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# GRAVITATIONAL AND COULOMB POTENTIALS INTERFERENCE IN HELIOSPHERE

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**Abstract**

Interference of gravitational and Coulomb potentials in the entire heliosphere is considered, it is being manifested in generation of two opposite flows of charged particles: 1) that are neutral or with a small charge to the Sun, and 2) in the form of a solar wind from the Sun. According to the Einstein — Smoluchowski relation $T_e(R) = eD_e / \mu_e \sim (E/N)^{0.75}$ based on the $N$ experimental values (heavy particles number density — the $n_e$ electron concentration), the $T_e$ electron temperature in the entire heliosphere was for the first time analytically calculated depending on the charge of the Sun and distance to it $R$. Calculated values of the registered ion parameters in the solar wind were compared with experimental observations. Reasons for generating the ring current in inhomogeneous heliosphere and inapplicability of the Debye theory in describing processes in the solar wind (plasma with current) are considered

**Keywords**

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

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**Introduction.** The problem of interaction (interdependence, intervention, conjugation or interference) between the positive charge of the Sun electric field (EF) and its gravitational field was delivered by A. Eddington [1]. His discovery that there should be certain separation of charges in the Sun is usually ignored, since the effect obtained as a result of analytical calculations is "absurdly weak" on the surface and inside the Sun [1]. Applying the method of generalized mathematical conjugation (MGMC) [2], our work proves that presence of the "absurdly weak" positive charge in the Sun is leading to significant "mysterious" phenomena [3, 4] in all heliospheres and geospheres making them completely ionized. These phenomena are determined by interference of electric and gravitational potentials in heliospheres and geospheres inhomogeneous in the $N(R)$ particles number density. If global current is present in the heliosphere [2–4], these phenomena are extremely significant in the solar corona at the $R$ distances of more than 8,000 km from the Sun surface and onward, where the particles number density drops sharply with altitude due to gravity. This is follows from the Paschen's law in heliosphere of the charged Sun.

According to Paschen's law, the energy of a charged particle is determined not only by the $E(R)$ EF strength, but also by the path length, where a charged particle gains energy in the EF, i.e., by the $N(R)$ particle number density or by the $E/N$ parameter. This law is used here to describe "mysterious" phenomena in heliosphere inhomogeneous in the $N(R)$ [2–4]. MGMC is understood as a method of transferring mathematical models from the studied areas of natural sciences to areas that were not studied sufficiently [2]. Using MGMC [2–4], let us explain by electric and gravitational fields interference several "mysterious" phenomena in the heliosphere and construct the electron temperature profile in the entire heliosphere based on the Nernst — Townsend relation:

$$T_e = \frac{eD_e}{\mu_e \left(E/N\right)^{\zeta}}, \qquad (1)$$

where $D_e$ is the electron diffusion coefficient; $\mu_e$ is the electron mobility.

Power approximation (1) in experimental measurements of temperature ($eD_e / \mu_e$) and other parameters describes perfectly the dependence of various transport processes rates in the gas-discharge plasma [2]. According to MGMC, we will apply this approximation for analytical calculations of the electron temperature in heliosphere assuming the $E/N$ parameter to be the most important in the heliosphere gas-discharge plasma [2]. The $E^2/(NkT)$ value characterizes the ratio of the external electric force energy strength in relation to the medium pressure. This qualitatively explains relationship (1). Electric force activates the medium and maintains a new ionization excited state in it, i.e., plasma and plasma structures with weak electroneutrality violation (EV) in plasma with current acting as a new phase state in the medium activated by this field [2].

Use of satellites ensured accumulation of vast amount of material [5–7], which is inconsistent with theories of plasma transport processes in the neutral heliosphere. Despite hundreds of scientific papers [5], there is still no observationally verified understanding of causes responsible for the ionic composition and the existence of solar wind (SW) filling inhomogeneous and completely ionized heliosphere at supersonic speed. Let us list the questions requiring a comprehensive answer.

1. What explains the motion of heavy multiply ionized iron ions ($Fe^{6+}$, …, $Fe^{12+}$) in SW from the Sun, which relative mass is enormous, and cross-sectional

dimensions (windage) are negligible [6, 7]? This degree of iron ions ionization in SW indicates the electron temperature of about $2{\cdot}10^6$ K in the solar corona. At the same time, ions from $Fe^{5+}$ to $Fe^{1+}$ with significantly higher windage are not registered in SW. Literature available to the authors of this work provides no explanation for these “mysterious” facts.

2. Why is the electron temperature not decreasing far from the Sun, which is the source of energy with surface temperature of 5,700 K, but increases by hundreds of times with distance from the Sun of about $(1–2) \cdot 10^6$ K at distances $R$ equal to $(10–30)R_S$, where $R_S$ is the radius of the Sun [8, 9]?

According to the existing concepts based on the neutral SW model, its velocity in the expanding corona smoothly increases due to a decrease in plasma density without experiencing any jumps [10, 11]. In this case, mathematical models of the expanding neutral gas are providing a decrease in temperature with expansion of the plasma flow with distance from the energy source, i.e., from the surface of the Sun [12]. As a result of radio occultation observations [13], it was established that in the corona at a distance of $(10–20)R_S$ from the photosphere there is a region of sharp increase in the SW velocity from 50 to 450 km/s. Work [12] indicates the fact that to explain heating of plasma at distances from the Sun of $(10–30)R_S$ to $(1–2) \cdot 10^6$ K requires a certain “mysterious” heating source in the corona region. However, this source was not detailed in [12, 13] either theoretically, or experimentally, and remained “mysterious”. Within the framework of the electrically neutral heliosphere model, mechanisms responsible for heating the solar corona up to $(1.5–2) \cdot 10^6$ K and causing its expansion from the Sun in the $(10–20)R_S$ region in the form of SW are not clear [5–7, 9–13]. Further, mechanism of the EF corona nonuniform heating is discussed on the basis of (1).

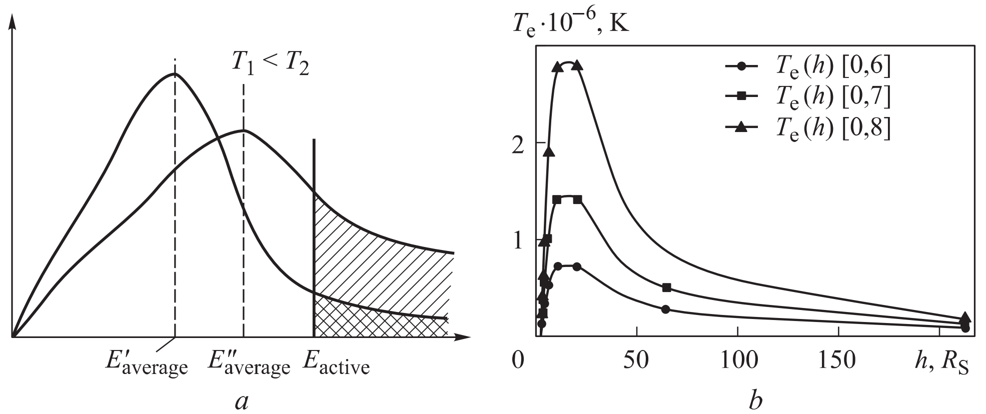
Charged particles heating by a long-range EF of the positively charged Sun [2–4] leads to a sharp increase in the protons and alpha particles velocity in SW in the $(10–20)R_S$ region established experimentally [13]. These questions are fundamental and require detailed comprehensive studies and discussions on the basis of unified model of a giant gas discharge in heliosphere [2]. Without solving these questions, it is impossible to discuss modern achievements in the theory in heliogeophysics [9, 14]. Let us dwell on the history of determining the solar charge.

**Brief history of research on Coulomb and gravitational potentials interference in the Sun and in the heliosphere.** Studying the influence of stellar charge on phenomena in the region of their surface began with the work of S. Rosseland. In 1924 he presented the work "Electric state of a star" [15] submitted to the magazine by Eddington. Rosseland was the first to combine in it the Boltzmann distribution of electrons and protons distribution in a star with gravity. All the Rosseland ideas and arguments about the star positive charge [15] were brought by Eddington in [1] to an estimate for the Sun of the EF strength on the Sun surface of $6.3 \cdot 10^{-6}$ V/m, which corresponds to the charge deficit of about 1 electron per million tons of matter. Eddington called this result "absurdly weak". We prove here that the Sun charge "absurdly weak" values obtained on the basis of the positive ions types analysis registered in SW lead to "mysterious" and extremely significant phenomena in the entire heliosphere and Earth ionosphere affecting the people well-being.

Describing private phenomena in the heliosphere, different authors receive opposite results on the Sun charge magnitude. So, work [16] uses the value of the Sun negative stationary charge of $10^{18}$ C ($3 \cdot 10^{27}$ CGSE) to explain the separate effect. Consequently, the problem of the Sun charge importance can be solved only by using comprehensive (joint) explanation of all the "mysterious" phenomena observed in heliosphere. Importance of the uncompensated space charge for the plasma transport processes in heliosphere was presented by I.S. Shklovsky in [17]. He stressed that a single uncompensated ion per $10^{10}$ compensated ions was enough so that the resulting electrostatic field could not escape observation. Reports [3, 4] were the first to inform on the importance of uncompensated charge of the Sun at the "absurdly low" level of 7.5 uncompensated by electrons per $10^{36}$ compensated nucleons for certain "mysterious" phenomena in the SW and in the entire heliosphere.

**Model of current discharge in heliosphere.** In the heliosphere model under consideration, EMF is determined by the Maxwellization processes (Maxwellian velocity distribution) of the electron distribution function, their heating in the Sun EF and constant departure of part of high-energy electrons (Figure *a*) far beyond the positively charged heliosphere (beyond the Earth orbit) [2–4]. These high-energy electrons could be called the runaway electrons. Due to the lack of electrons in the entire heliosphere, complete Debye compensation of the Sun effective positive charge does not occur. Increasing effective positive charge and EF is possible with distance from the positively charged Sun. According to calculations made, electron temperature is significantly increasing up to 170 eV at distances of $\approx$ (10–20)$R_S$ (Figure *b*). Original results of analytical and numerical calculations obtained on the basis of this model are presented below.

Answer to the question, why there is no Debye screening of the Sun positive charge in heliosphere, is detailed in [2]. This is due to the constant




Electron energy distribution functions depending on temperature (*a*)
and electron temperature dependence on distance to the Sun
at the ζ parameter values with the Sun charge of 1,441 C (*b*)

departure of high-energy (runaway) electrons from the Sun and the heliosphere and to the arrival of slower electrons and negatively charged dust. Difference in the velocities of departing and returning charged particles from the Sun and to the Sun leads to the charge rotation (cycle) dynamics (cycle ion and electron fluxes) in heliosphere and to a quasi-constant uncompensated effective charge of the Sun. This effective positive charge of the Sun and of the inner heliosphere with current (constant flux of departing electrons from heliosphere) accelerates return of the negative charge to the Sun, but does not completely compensate the charge of the Sun and of the heliosphere. It will be shown below that at distances of $(10–20)R_S$, the electron temperature reaches its maximum values of ≈170 eV, which leads to intensification of the high-energy electrons' departure processes from this region of heliosphere. Due to a sharp drop in the $N(R)$ particles number density in the gravitational field in heliosphere, the entire heliosphere appears to be an active medium that increases its effective space charge in the Sun positive charge field. Thus, works [3, 4] described for the first time the property of heliosphere inhomogeneous in particle density to be the *active plasma medium* to enhance the solar charge effective influence on charged particles at distances larger than $10\,R_S$. A standing shock wave is generated here [3, 4] related to the $N(R)$ particle number density of the $E/N$ electric field. Positively charged standing wave in heliosphere and the Sun accelerate towards the Sun the slow negatively charged particles and accelerate particles charged positively from the Sun. Formation of the $E/N$ shock wave or of the striation, which strengthens the Sun effective space charge, leads to a sharp increase in the velocity of protons and alpha particles in SW established by [13] in the (10–20)$R_S$ region. Previously, this phenomenon had no intelligible explanation.

**Comparison of Coulomb and gravitational interactions between elementary particles.** Since 1924, S. Rosseland, A. Einstein, E. Schrödinger, A. Eddington, P. Dirac and others were trying to create a unified theory of electromagnetic and gravitational fields [1, 15, 18]. Thus, the ratio of the $Ke^2/r$ electric potential to the $Gm^2/r$ gravitational potential is equal to $Ke^2/(Gm^2)$ for two identical particles with the $m$ masses and the $e$ charges. For an electron, this gives an enormous value of $4.17 \cdot 10^{42}$, it is the Eddington number. Dirac noted that a large number is used to measure the ratio of the electric force to the gravitational force acting between the electron and the proton, i.e., $Ke^2/(Gm_pm_e) \approx 2.27 \cdot 10^{39}$. Here $m_p$ and $m_e$ are the masses of the proton and of the electron. To describe real objects with uncompensated charges, this approach was further developed in 2009 [19–21].

**Modification of the Eddington — Dirac method.** Gravitational and Coulomb forces in objects with dimension of $10^{-16}$–$10^{26}$ m were compared in [19–21]. Here, the ultimate goal was to create a theory of these fields' interference for massive objects in space and their parts. Mass in gravitating bodies is determined by the mass of nucleons. Nucleon masses are 1,836 times greater than the mass of electrons; therefore, mass of any structure is determined by the number of $M$ nucleons in it (taking into account the mass defect). The structure charge is characterized by the $Z$ uncompensated charges number. According to Coulomb and Newton laws, the $K(\alpha_{i1}M_1e)(M_2\alpha_{i2}e)/R^2$ and $G(M_1m_p)(M_2m_p)/R^2$ forces should be compared in space gravitating objects, for example, with an arbitrarily distributed charge along the radius, when comparing gravitational and electric repulsive forces. Here $K = 1/(4\pi\varepsilon_0)$, $\varepsilon_0$ is the electric constant; $\alpha_{i1} = Z_1/M_1$ is the degree of the protons' space charge non-compensation in the structure; $M_1$ is the total number of nucleons in the structure sphere with the $R$ radius; $\alpha_{i2} = Z_2/M_2$ is the degree of the $Z_2$ protons' space charge non-compensation in the studied volume, for example, on the star surface at the $R$ distance from its center; $M_2$ is the number of nucleons in this volume. Degree of the $\alpha_i$ structure space charge non-compensation is understood as the ratio of the $Z$ positively charged ions number non-compensated by electrons, which form space charge of the entire structure, to the $M$ number of nucleons. This corresponds to [1], [17], and [2–4]. Thus, a method was proposed for studying electrical parameters of the Sun, other stars, galaxies and their systems by ionic composition of the corresponding winds. With this approach, Eddington number and Dirac number are modified into the following number:

$$\frac{Ke^2}{Gm_e{}^2} = 4.17 \cdot 10^{42} \to \frac{Ke^2}{Gm_e m_p} = 2.27 \cdot 10^{39} \to \frac{K\alpha_{i1}\alpha_{i2}e^2}{Gm_p{}^2} = 1. \qquad (2)$$

Condition (2) determines the 3D instability of a star or its systems (analogous to 2D rotational instability), i.e., transition from cumulation to dissipation. Instability arising for cumulative dissipating (CD) structures due to electroneutrality violation (EV) would be called the Vysikaylo 3D instability [3, 4, 19–21]. Cumulation is determined by gravity, and dissipation is determined by the Coulomb forces. It follows from (2) that:

$$(\alpha_{i1}\alpha_{i2})^{0.5} = \alpha_i = 0.9 \cdot 10^{-18}, \qquad (3)$$

where $\alpha_i$ is the critical degree of the charged body substance EV. When this limit is reached, the body or system of bodies ceases to contract under the gravitational forces impact, and fragments of charged plasma start to being ejected from the body surface, as in the case of rotational instability, in the form of stellar, solar wind or even winds [3, 4, 19–21]. According to (3), here the role of a one non-compensated charge per $10^{18}$ compensated ones is considered. The $\alpha_i = (\alpha_{i1}\,\alpha_{i2})^{0.5}$ parameter determines transition in the CD structures from compression to Coulomb loosening (sputtering and dispersal) of charged matter of nucleons, for example, charged centers of galaxies scatter from each other, thereby filling the "mysterious" Einstein Λ-term with meaning [21]. The $\alpha_i$ parameter is determined by two parameters: 1) the $\alpha_{i1}$ structure EV parameter as a whole; 2) the EV parameter of the $\alpha_{i2}$ element studied for the Coulomb instability and selected in the charged CD structure, where charge compensation is impossible for one reason or another [2–4, 19–21]. (Charge compensation in the atomic nucleus by the shell electrons with nanometer-sized de Broglie wavelengths is impossible due to the quantum properties of electrons). The structure could have the value of $\alpha_{i2} = 1$, 1/2, 1/3 or less. The $\alpha_{i2} = 2$ or 10 values are impossible due to impossibility of cumulating only protons into the atomic nuclei. For a nucleus with 10 protons and 10 neutrons: $\alpha_{i2} = Z/M = 1/2$.

**Classification of the charged stellar wind.** Vysikaylo instability (dispersion from a charged structure) starts primarily with the protons, since the $\alpha_{i2} = Z/M$ parameter of them is maximum $\alpha_{i2} = 1$. This instability (reflection by a Coulomb mirror), according to (3), is realized with the $\alpha_{i1} \geq 8.1 \cdot 10^{-37}$ parameter for the entire star. At these values of $\alpha_{i1}$ and $\alpha_{i2}$, the $\alpha_i$ value will reach the Vysikaylo limit [3, 4, 19–21]. And when the EV parameter for a star reaches $\alpha_{i1} \approx 8.1 \cdot 10^{-37}$, the reflecting Coulomb mirror appears for protons, and a free path to a charged star becomes impossible. Stellar charge, hydrogen ionization in their crowns and Vysikaylo instability for protons [3, 4, 19–21] determine the overwhelming number of protons (up to 90 %) experimentally registered in all energy, mass and pulse flows (EMPF) in space. Possible range of the $\alpha_{i2}$ parameter values for elements cumulating on the attractor is $1 \geq \alpha_{i2} \geq 0$. Alteration in the ordinary space gravitating stationary objects parameters lies in the range of $\alpha_{i1} \approx 0 - 0.9 \cdot 10^{-18}$. This concerns the ordinary astronomical objects. However, the value of $\alpha_{i1} = 10^{-18} - 1/2$ is possible in quantum stars and black holes with electron and meson membranes compressing nucleons, as for the atomic nuclei [3, 4, 19–23].

If in heliosphere down to the Earth negative charges that could implement the Debye screening of the Sun effective charge are missing, then knowing the Sun parameters and the EV parameter providing the Coulomb mirror reflecting protons in the Sun $\alpha_{i1} \approx 0.81 \cdot 10^{-36}$, we can find the effective charge of the Sun $q_S = e\alpha_{i1}N_S = 154$ °C and the electric field strength on its surface $E_S = K e\alpha_{i1}N_S / R_S^2 = 2.86 \cdot 10^{-6}$ V/m. EF is negligible on the surface of the charged Sun. It is 2.2 times less than the electric field strength on the Sun surface analytically obtained in [1] by Eddington.

Alpha particles are also observed in SW [10, 24], for which $Z/M$ = 1/2. Consequently, positive charge of the Sun, which plays the role of Coulomb mirror for alpha particles, is at least 2 times greater than 154 °C, and the resulting EF strength on the Sun surface is greater than $5.7 \cdot 10^{-6}$ V / m, which is 10 % lower than the value obtained by Eddington [1]. Thus, the EF strength values were determined close to those of Eddington.

Here, we have established the electric field strength near the surface of the sun by way based on the experimental registration of the positive ion types in SW. Although the same “absurdly weak” EF density values were obtained, as by Eddington, these EFs on the surface of the Sun reflect protons and alpha particles from the Sun and thereby generate SW [3, 4].

Let us show that it is precisely the EV of the entire Sun at this “absurdly low” level in accordance with the Paschen’s law that leads to formation of regions in the solar corona with the electron temperature of the order of $(1–2) \cdot 10^6$ K and of constant SW consisting of protons and other positive ions even without generating sound, shock and Alfvén waves in the solar corona. Due to the Sun insignificant EV, the Coulomb gravitational separation in the ions motion direction and their acceleration from the Sun appear in the corona. In this case, the EV influence on the Debye radius in the Sun is negligible ($\approx 10^{-18}$, according to [2, formula (2)]). Let us calculate values of heliosphere and of the Sun completely ionized plasma parameters by the type of positive ions in SW [6, 7].

**Method for calculating the solar charge on the basis of positive ions in the solar wind.** In our analysis of the ionic composition of SW in [3, 4], we were interested in a positive ion constantly present in SW with a minimum ratio of the charge number ($Z$) of the ion to its mass number ($M$) of nucleons $Z/M$ (taking into account the mass defect). The smaller this ratio is for positive ions constantly observed in SW, the higher should be the positive quasi-constant charge of the Sun for equality of Coulomb repulsive forces and gravitational forces of attraction. Data from the *ACE* spacecraft (*ACE Level 2 (Verified) Data SWICS 1.1*) for 2011 [6, 7] indicate the presence of the following ions in the SW: $C^{4+}$, $O^{5+}$, $Ne^{8+}$, $Mg^{6+}$, $Si^{6+}$, $Fe^{6+}$ ($Z/M = \ldots = 0.33$; 0.31; 0.39; 0.24; 0.21; 0.107). Last ion has the minimum value of $Z/M = 0.107$. Observation of this ion — $Fe^{6+}$ in the SW is possible, when the solar charge is $Q_S > 1{,}432$ C, i.e., with a nine fold increase in the solar charge, in comparison with the calculations by this method and taking into account only protons in the SW. Increasing number of times ionized iron ions and other ions with the ratio of $Z/M \geq 0.107$ are observed in SW. The iron ion ionized by 5 or fewer times in the SW is not registered, as well as positive ions with $Z/M < 0.107$, wherein the $C^{4+}$ and $O^{5+}$ are registered [6]. This experimentally observed fact provided grounds to estimate the solar charge at the 1.4 kC level [3, 4] and the electric field strength on the solar surface at $2.7 \cdot 10^{-5}$ V/m. Results obtained are based on accounting the types of ions in SW and are in perfect agreement with the results by Eddington [1] (electric field strength and the solar charge differ by 4.2 times).

It was proven that in the heliosphere completely ionized plasma there appears constant discharge of high-energy (runaway) electrons outside the heliosphere [2]. This makes it impossible to compensate the space charge of the Sun in the heliosphere and, accordingly, leads to generating the constant giant ring current in the heliosphere and possibly even the giant direct current in the galaxy. On this basis, a completely new SW mathematical model was analytically studied [3, 4], which takes into account the weak EV of the entire Sun mass and the completely ionized heliosphere with free electrons. According to the author, the effective uncompensated positive charge of the

Sun is responsible (as in an ordinary unipolar discharge on a charged needle and in the Franklin wheel, where electric or plasma wind appears) for removal and acceleration of the positively charged ions from the Sun. This assumption makes it possible to use all experience and knowledge obtained in studying the ordinary gas-discharge plasma for analytical calculation of the SW (positive ions) parameter values and obtaining new knowledge about the processes in heliosphere of the positively charged Sun, which is nonuniform in the $N(R)$ particle number density, as a giant anode in an inhomogeneous heliosphere discharge. Let us calculate the gas-discharge plasma parameters of the entire heliosphere and explain the experimentally observed maximum temperature of electrons in the heliosphere of the order of $(1–2) \cdot 10^6$ K [8, 9, 14].

**Calculations of the positively charged Sun and positive ion parameters in the solar wind.** According to the type of positive ions in the SW, the solar charge was determined to be 1.4 kC [3, 4]. Thus, conditions were set, under which protons and other positive ions with $Z / M > 0.107$ are reflected from the positively charged Sun. Positive charge in such structures appears due to escape of a small fraction of mobile electrons to distances larger than dimensions of the analyzed structure. Fast electrons leave the structure because of their enormous energy, which they acquire in electron-electron collisions (or electron distribution Maxwellization function processes). In this case, it is not important whether the charge is distributed over the entire Sun volume or is located on its surface, since the problem is assumed to be spherically symmetric and the EF strength profile outside the Sun does not depend on this. Accordingly, the considered solar plasma is quasi-neutral according to Shklovsky (see (1) [2]), but is not absolutely neutral $(\alpha_{i1} \neq 0)$. For the charge absolute screening charge at the Debye radius distance, the absolute neutrality condition should be satisfied, which implies complete plasma neutrality, and this is a myth. According to the proposed model and ratio:

$$\alpha_i = \frac{n_\mathrm{i} - n_\mathrm{e}}{n_\mathrm{i} + N} \ll 1.$$

Here $n_\mathrm{i}$ is the positive ion concentration; $n_\mathrm{e}$ is the electron concentration; $N$ is the concentration of neutral particles (atoms, molecules, etc.). Knowing the Sun quasi-stationary charge of $Q_\mathrm{S}$ = 1,400 C, it is possible to calculate the EF strength profile from the distance to the Sun.

The $n_\mathrm{e}(R)$ electron concentration profile in the heliosphere in [25, Table 5] is constructed from all the observed facts related to optical and radio brightness of the corona, as well as to chromosphere in different wavelength ranges and at different distances from the center of the Sun. Hydrogen plasma in heliosphere is assumed to be completely ionized [14]. Consequently, the $N(R)$ nucleon particle number density is of the same order of magnitude as that of electrons ($n_e(R) \sim N(R)$). Let us use the $n_e(R)$ profile to calculate the $E/N(R)$ profile in heliosphere [25]. Based on these data, the $E/N$ profile from the $R$ height above the Sun (Table) is constructed for various values of the Suns charge. The $E/N(R)$ EF strength (Td, Townsend) related to $N$ depends substantially on the $N(R)$ heavy plasma particles density and rapidly increases from photosphere to chromosphere.

**$N_H$ values [cm$^{-3}$] and $E/N$ [Td] (set by the solar charge) depending on the altitude above the Sun surface**

| $R$, km/r, $R_S$ | $N_H$, cm$^{-3}$ | $E/N$, Td | $E/N^{**}$, Td | $T_e$, °/ζ |
|---|---|---|---|---|
| 0,1 | $3.98 \cdot 10^{15}$ | $7.2 \cdot 10^{-7}$ | – | – |
| 1,000 | $3.16 \cdot 10^{13}$ | $9.0 \cdot 10^{-5}$ | – | – |
| 2,000 | $6.31 \cdot 10^{12}$ | $4.5 \cdot 10^{-4}$ | – | – |
| 3,000 | $1.99 \cdot 10^{12}$ | $1.4 \cdot 10^{-3}$ | – | – |
| 4,000 | $7.94 \cdot 10^{11}$ | $3.6 \cdot 10^{-3}$ | – | – |
| 6,000 | $2.51 \cdot 10^{9}$ | 1.14 | – | – |
| 8,000 | $1 \cdot 10^{9}$ | 2.86 | 26 | 15,524/0.8 |
| 10,000 | $6.31 \cdot 10^{8}$ | 4.53 | 40.8 | 22,249/0.8 |
| 15,000 | $1.99 \cdot 10^{8}$ | 14 | 126 | 54,870/0.8 |
| 70,000 | $7.94 \cdot 10^{7}$ | 30 | 279 | 80,409/0.7 |
| 280,000 | $1.26 \cdot 10^{7}$ | 116 | 1,079 | 208,853/0.7 |
| 420,000 | $5.01 \cdot 10^{6}$ | 223 | 2,074 | 329,209/0.7 |
| 700,000/2 | $1.58 \cdot 10^{6}$ | 452 | 4,204 | 534,802/0.7 |
| 1 400 000/3 | $3.98 \cdot 10^{5}$ | 798 | 7,421 | $0.9 \cdot 10^{6}$/0.7 |
| 2 800 000/5 | $6.31 \cdot 10^{4}$ | 1812 | 16,851 | $1.43 \cdot 10^{6}$/0.7 |
| 6 200 000/10 | $1 \cdot 10^{4}$ | 2942 | 27,361 | $2.0 \cdot 10^{6}$/0.7 |
| 13 000 000/20 | $2.51 \cdot 10^{3}$ | 2,973 | 27,649 | $2.0 \cdot 10^{6}$/0.7 |
| 44 000 000/65 | $1 \cdot 10^{3}$ | 701 | 6,519 | $0.73 \cdot 10^{6}$/0.7 |
| 150 000 000/215 | $6.31 \cdot 10^{2}$ | 97.7 | 909 | $0.18 \cdot 10^{6}$/0.7 |

*Note.* Calculation for $Q_S$ = 154 C third column, for $Q_S$ = 1,432 C fifth column.

In the photosphere region, where the $N$ particle number density is high, the $E/N$ parameter is very small. Consequently, according to Eddington, Paschen, Stoletov and Townsend, influence of the external EF on convective processes in photosphere is “absurdly weak”. $E/N$ parameter in chromosphere rapidly increases with altitude due to a sharp drop in the plasma particle number density with height and reaches the breakdown values (30 Td) in corona at the altitude of 15,000 km even for the solar charge of 154 C, which leads to significant heating of electrons by EF in this areas of the positively charged Sun [3, 4]. Here and above, the rate constants of reactions and transfer of charged particles are essential, and, according to Paschen's law in the interpretation by Stoletov and Townsend, are essentially determined by the $E / N$ parameter [2]. Nonequilibrium plasma is already being implemented here.

**Discovery of the *E/N* related to electric field shock wave in heliosphere.** According to the proposed model, nonequilibrium plasma is generated in the lower solar corona in the external EF of the positively charged Sun with $E / N$ values much higher than the breakdown fields in hydrogen plasma (see Table). This significantly strengthens the SW from the zone of electron maximum temperature values (or the $E / N$ parameter) into space, i.e., removal of quasi neutral plasma, as in conventional plasmatron or in Franklin wheel with a discharge on charged needles. Helium ions are observed in the SW. This means that all the Sun parameters are by 2 or 4 times higher (depending on whether helium is ionized 2 or 1 times). If we take into account the presence of 6 times ionized iron registered in the SW [6, 7], this leads to a 9.3-fold increase in the solar charge and in these parameters ($E / N^{**}$) and establishment of breakdown values already at the altitude of 8,000 km above the Sun.

At the solar charge of 1,432 C, temperature profile was calculated in [3, 4] over the entire heliosphere (see Table). At $E / N < 100$ Td, the $\zeta = 0.8$ value (according to the data of [26] for hydrogen plasma) was used to calculate the electron temperature values. For $E / N > 100$ Td, the $\zeta = 0.70–0.75$ was used in calculating the electron temperature values. Using (1) for simulating the phenomena in the heliosphere with EF is due to the efficiency of hydrodynamic models based on such concepts for charged particles as the diffusion coefficient, drift velocity, and electron temperature. The process of establishing parameters in heliosphere requires detailed experimental studies, which were performed with hydrogen plasma [26]. V.V. Izmodenov [9] relies on kinetic and magnetic hydrodynamic approach to describe phenomena in the heliosphere. Similarly, using the electrohydrodynamic approach laid down by Eddington, Stoletov, Townsend and their followers, including the authors of [3, 4], let us prove its effectiveness in explaining "mysterious" phenomena in heliosphere. EF role in the region of up to $8 \cdot 10^3$ km from the positively charged Sun surface is not significant; the $E / N$ parameter corresponds to parameters in gas-discharge tubes. The use of electrohydrodynamic concepts is quite reasonable here, as well as up to $70 \cdot 10^3$ km above the Sun, where the $E / N$ parameter still corresponds in values to those observed in the laboratory hydrogen plasma. Application of knowledge gained in the study of processes in laboratory plasma is fully justified.

In the (10–30)$R_S$ region, the $E / N$ parameter reaches its maximum values never observed in conventional laboratory plasma. For such $E / N$ parameter values, numerical calculations of electron temperature, diffusion coefficients and drift velocity values are missing. Calculations for plasma in air are known up to $10^3$ Td, and the proposed approximation — (1) is valid. So far, the only method for studying electron temperature in this region of the $E / N$ standing shock wave is currently the method of extropolating relation (1) to the region of such out-of-limit values of the $E / N$ parameter and electron temperature of 170 eV. We believe that these local plasma characteristics obtained from direct experiments in laboratory plasma could also be used to describe plasma in heliosphere as long as concepts such as drift velocity and electron diffusion are making sense.

Using the hydrodynamic approach based on experimental measurement of the diffusion and drift coefficients, it is possible to exclude problems arising in the defective theories associated with numerical calculations of the electron distribution function in the two-term approximation taking into account only the pair collisions. Criticism of such models could be found in works by A.A. Vlasov.

There are no more sophisticated models and approaches to explain the considered “mysterious” phenomena than those proposed in this work. Electron temperature profiles as a function of the $\zeta$ parameter are shown in Figure *b*. Maximum electron temperature of $(1–2) \cdot 10^6$ K is achieved at distances from the Sun in the region of (10–30)$R_S$. Electrons in this region due to the high temperature “escape” from the heliosphere at the highest velocity; quasi-stationary spherical space charge layer (20–30)$R_S$ thick accelerating from the Sun and positive ions with $Z / M < 0.1$ are generated. The traveling layers of space charge were first discovered in semiconductors by J. Gunn [27], and he called them the EF shock waves. Gunn discovered that a strong EF applied to the gallium arsenide crystal caused current oscillation at the frequency exceeding $10^9$ Hz. As established by Gunn [27], crystal width significantly determines the oscillation frequency, which clearly indicates the 3D dimension character of the Gunn effect. Therefore, description of the Gunn effect within the framework of 1D models dominating in literature is pseudoscientific. Gann’s theoretical analysis led him to propose a mechanism resembling a shock wave [27]. This approach turned out to be fruitful also in discovering a standing EF shock wave in the gas-discharge plasma [28–31].

EF standing shock waves in plasma were predicted in [28] while analyzing the arrest of ambipolar plasma drift by gas pumping and the transition of transport processes to ambipolar plasma diffusion caused by weak violation of electroneutrality. EF standing shock waves in quasi stationary discharges were visualized in [29] (see [2, Fig. 2]). Work [29] found: 1) $E / N$ super breakdown values in the jump (exceeding by 10 % for a plasma column with dimension of 20 cm); 2) more intense glow in the self-generating elliptical (almost spherical) quasi stationary plasmoid, i.e., “sun”, centimeter-sized. The $E$ measured profiles were analyzed analytically in [30] and numerically in [31] within the 1D model framework. The $E$ and $E / N$ increase in experiments was explained by the more intense ejection of positive ions onto the walls of the discharge tube from the “sun” of the 3D shock elliptical self-generating wave of an EF, i.e., of the positively charged quasi neutral, but not absolutely neutral, structure. Thus, to simulate the EF shock waves, 2D or 3D models are required taking into account the Poisson equation. Let’s return to the global discharge in the entire heliosphere.

The fact that a $20R_S$ thick space charge spherical layer is generated in perfect agreement with observations of the SW velocity increase of 50–450 km/s [13]. Maximum values of the electron temperature and of the $E / N$ parameter is reached here; these values significantly depend on the effective charge of the Sun. This is also consistent with an assumption that 6 times ionized iron ions are registered in the SW [14]. Even greater violation of the plasma electroneutrality than $\alpha = 10^{-36}$ should be expected in this area. This follows from Eddington estimates and calculations on the SW ionic composition provided in [3, 4] and observed on the Sun. These problems and more self-consistent and complete theory of the standing shock wave related to the $N(R)$ plasma particle number density of the $E / N$ EF strength would be considered below.

Let us discuss results obtained in [3, 4] on the basis of a simplified model that assumes concentration of the heliosphere charge only in the Sun (without taking into account the space charge profile in heliosphere). According to experiments, maximum temperature does not exceed $2 \cdot 10^6$ K [8, 9, 14]. These values are consistent with the assumption that 6 times ionized iron ions could be observed in the SW [6, 7], i.e., the effective charge of the Sun is about 1,400 C. These data make it possible on the basis of analytical calculations [3, 4] to assert that a standing shock wave of the related EF is generated in the region of $20R_S$ size at the distance of $10R_S$ from the solar surface, and it is characterized by the electron temperature of $2 \cdot 10^6$ K ($E / N$ ($R$) parameter profile obtained within the approximate model [3, 4]) is presented in the Table, and the corresponding electron temperature profile is shown in Figure *b*). If Gann discovered traveling shock waves (the author considers them to be analogs of ordinary traveling gas-discharge striations known to Faraday), and P. Vysikaylo [28–31] studied the standing shock waves of the EF strength ($E$), then works [3, 4] discovered standing shock waves of the $E / N$ parameter arising not as a result of the EF strength increase, as in [28–31], but as a result of a sharp drop in the $N$ gas density and corresponding increase in the electron path length in the shock wave region as compared to the heliosphere regions located closer to the Sun. According to data provided in [25, Table 5], it is possible to establish in which regions of heliosphere processes of spherically symmetric convective removal of plasma (electrons and protons) are taking place, and where along with convective processes the processes of ionization or of protons and electrons production are already significant. The main question is reliability of the data given in [25, Table 5].

The $N_{\text{H}} \sim R^{-2}$ law should work in regions of the protons' convective removal (and electrons entrained by them) from the Sun. Where ionization of hydrogen coming from the outer heliosphere to this part is essential, this law of decrease in the plasma particles concentration should shift towards weaker dependence on the distance to the Sun. According to data provided in Table, dominance of plasma particles free transport is observed in the region at the distance of (10–30)$R_{\text{S}}$ ($6.2 \cdot 10^6$ km) ($R_{\text{S}} = 18 \cdot 10^6$ km). In the region at a distance of 65$R_{\text{S}}$, local ionization processes of hydrogen atoms entering this region from space are becoming more significant. The $E / N$ parameter reaches its maximum value at distances from the Sun of the order of (10–20)$R_{\text{S}}$ and then begins to decrease by up to 27 times at distances of the order of an astronomical unit, i.e., the radius of the Earth orbit. Further and according to [32], the $N_{\text{H}} \sim R^{-2}$ law is restored again; and, therefore, the $E / N$ parameter is not changing or altering with the distance to the Sun. Since the $E / N$ parameter values are extremely high in these regions, an increase should be expected in the total positive charge (solar heliosphere) in the entire heliosphere taking into account the processes of ionization in heliosphere being an active medium that strengthens solar EF.

**Calculation of protons and alpha particles energy in the Earth area.** The proton Coulomb potential energy at the $r$ distance from the positively charged Sun is equal to $W = KQ_{\text{S}}e / r$, $r$ is the astronomical unit. All this potential energy could transfer into kinetic energy of a charged particle far from the Sun, if the particle is not exposed to inelastic collisions that significantly change its kinetic energy. For the protons generated in the region of the Earth orbit, we have $W = 1.5 \cdot 10^{-18}$ J (9.2 eV).

According to the SW experimental studies in the Earth area, the proton velocity there reaches values of $V$ = 400–1,000 km/s [24]. If these protons came from the Sun region, then, knowing from experiments the $V$ average velocity of protons in SW near the Earth, kinetic energy of protons in SW could be evaluated: $W = mV^2/2 = 13.36 \cdot 10^{-17}$ J (from 835 to 5,200 eV). This energy is acquired by protons arising in the solar corona and accelerated by its positive charge to such velocity values in the Earth region. The mean free path, at which protons flying towards the Earth do not experience collisions with particles, could be estimated by the following formula:

$$L = \frac{1}{\sigma N}.$$

Here $\sigma$ is the effective cross section for collisions of protons and electrons with the hydrogen atoms and molecules $(2–4) \cdot 10^{-17}$ cm$^2$ [33, 34]. In this case, protons generated at distances from $(6–13) \cdot 10^6$ km ($(10–20)R_S$) would arrive to the Earth without collisions. Potential proton energy at these distances during their generation would be $(1.6–0.8) \cdot 10^3$ eV. If the charge of the Sun is ≈ 1,400 C, then protons, alpha particles and even 6 times ionized iron ions are reflected from the Sun (see [2, Fig. 5]). In this case, the electron kinetic energy focused (cumulated) into this region ($(10–20)R_S$) from the surrounding space with such charge of the Sun would be of the same order of $(1.6–0.8) \cdot 10^3$ eV. On the one hand, this leads to heating the solar corona by high-energy electrons. On the other hand, high-energy electrons move away from the Sun and thereby cool the solar corona. Contribution of these balanced opposite flows leads to the fact that electron temperature in the solar corona is determined by the $E/N$ local parameter, as in the conventional gas discharge. This is due to the essential role of electron-electron collisions or Maxwellization of their energy distribution function. If the law of electron temperature alteration from $E/N$ for a gas discharge in hydrogen ($T_e \propto (E/N)^{0.7–0.8}$) also works at giant values of $27 \cdot 10^3$ Td, then knowing the electron temperature of 1 eV at 30 Td from (1) the $T_e \approx 170$ eV temperature at distances of $(10–20)R_S$ is obtained, where $T_e \propto (E/N)^{0.75}$. This corresponds to temperature of $2 \cdot 10^6$ K. Such values are observed in experiments [8, 9, 14, 35]. Charge of the Sun (~ $10^3$ C) due to a sharp drop in the $N(R)$ particle number density with the $R$ altitude above its surface leads to the following phenomena:

1) $E/N$ shock wave is generated with maximum values of up to $3 \cdot 10^4$ Td and, accordingly, with the electron temperature of up to $2 \cdot 10^6$ K at distances $(10–20)R_S$ (see Table, Figure *b*); spherical space charge layer with such electron temperature has the radial size of $\approx 20R_S$;

2) positively charged ions ($Z / M > 0.107$) are constantly flowing from this layer of the Sun corona, for which gravitational forces are less than the Coulomb repulsive forces from the positively charged Sun.

The Sun reflects with a Coulomb mirror not only protons and alpha particles, but also the 6 times ionized iron ions; therefore, energy of the positively charged particles near the Earth increases by 2, 4 and 9 times in relation to the calculation values received on the basis of the Sun charge of 154 C. Consequently, experimental observations in the interplanetary space of the SW ion mass and charge composition make it possible to obtain valuable information not only about the solar atmosphere, but also about the Sun average parameters (its total charge, profile of the related EF strength and temperature of electrons and ions in the entire heliosphere), and make a significant contribution to verification of models of processes occurring on the Sun. Analytically calculated profile of the electron temperature in heliosphere depending on the distance to the Sun is presented in Figure *b*. The model assumed that plasma in hydrogen in the heliosphere possesses the same properties as in the case of conventional gas discharge and is characterized by the $E / N$ parameter. Dependence of the electron temperature on this parameter is chosen as a power law in the range of $\zeta = 0.6–0.8$. Data presented in [26] in the range of 0.02–200 Td in the molecular hydrogen plasma are described according to (1) with the accuracy of 5 %. Tendency is observed in this range for the $\zeta$ parameter to increase from 0.5 to 0.8 at $E / N = 0.02–100$ Td, and then $\zeta$ decreases to 0.7 at $E / N = 100–212$ Td. To calculate the electron temperature profile in heliosphere, the power exponent was chosen equal to 0.75, and the solar charge was 1.432 kC. As a result, maximum electron temperature of 170 eV, or approximately $2 \cdot 10^6$ K in the $(10–30)R_S$ region, was obtained analytically. This indirectly proves that we are dealing with the same phenomenon, i.e., ordinary hydrogen plasma, but in a large-scale solar laboratory and with enormous $E / N$ values that was never observed in laboratories on Earth. Charges of the Sun found are of small values, even in comparison with the negative charge of the Earth (~ 500 kC [36]). This indicates that the heliosphere main charge is concentrated in the shock wave of the $E / N$ — related electric field strength.

Prolonged violation of electroneutrality at the level of $\alpha_S \sim 10^{-36}$ (which Rosseland guessed back in 1924 [15]; and in 1926, using his method, Eddington analytically calculated the charge of the Sun [1]), leads to noticeable effects in the entire heliosphere. It was shown that such an insignificant charge, similar to a small fluctuation of about 0 (taking into account the energetics of processes occurring in the Sun) near the Sun surface nevertheless leads to significant “mysterious” phenomena of electron heating throughout the heliosphere at distances of more than $8 \cdot 10^3$ km from the surface of the Sun in EF of the positively charged Sun. Eddington did not take into consideration that at distances of (10–30)$R_S$ the gas particles number density decreases faster [25] than the EF strength from the distance to the solar surface [3, 4]. Such weak EFs at these distances from the Sun are the main energy reservoir feeding the SW charged particles and all the “mysterious” phenomena in heliosphere. According to Eddington, time scale of this insignificant (absurdly small for the surface of the Sun) charge corresponds to the lifetime of the Sun or alteration in its average surface temperature. It perfectly corresponds to the average quasi-constant electron temperature of $(1–2) \cdot 10^6$ K even at distances of (10–30)$R_S$. The scale of change in the charge of the Sun corresponds to its size, and the scale of the corresponding response of the altering electron temperature corresponds to a greater extent to changes in the $N/R$ nucleons density in geosphere than to changes in the charge of the Sun. The time of the Coulomb forces action is long and corresponds to lifetime of the Sun and to its basic parameters (density, radius, mass, etc.).

**3D-structure of dual energy, mass and pulse flows in plasma cumulative dissipation structures at the Coulomb and gravitational potentials interference.** Any structure with free electrons experiences processes of Maxwellization or energy flow into the region of high-energy electrons. Small part of the electrons constantly leaves the plasma structure and thereby charges it with a positive charge, which brings back part of the low-energy electrons to the positively charged plasma structure. Returning the negative charge to the plasmoid provides its dynamic surface tension and generation of the electronic membrane [22, 23]. Convective cumulation processes in the region of a positively charged star are determined by gravitational forces acting on all particles with mass, as well as by Coulomb forces acting on electrons, negatively charged dust grains and negative ions. If positive ions have the $Z/M$ ratio higher than the critical value (for the Sun, it’s $Z/M = 0.107$), then the Coulomb forces for such ions exceed gravitational forces, and the ions are repelled by Coulomb forces and are generating EMPF from the star or SW, in the case of the Sun. The positive ion flux entrains free electrons, and due to the small mass of protons, the quasi-neutral plasma spreads throughout the heliosphere.

According to the virial theorem [37] or Newton’s third law [38], only one half of the gravity potential energy and the Coulomb potential ($U$) could be converted into kinetic energy ($T$) of particles focused to the positively charged Sun

($T = -(1/2)U$). The other half of potential energy ($(1/2)U$) should dissipate into the space surrounding the Sun. This conclusion from the virial theorem or the Newton's third law was first noted in [38]. Another important law follows from the virial theorem for CD structures, i.e., the faster the focusing processes occurs the faster are processes of dissipation of half of the potential energy [38]. Processes of convective dissipation (or forces of the medium resistance to cumulation forces) are responsible for dissipation of half of the potential energy. According to these concepts, bi-cyclones or structural turbulence were discovered in [38] (cyclone and anticyclone co-organization into a single convective CD-structure with dual properties, both cumulation of convective flows into a structure and, and, at the same time, convective dispersion of dissipative flows from the structure, [38]). The first part of energy dissipating from the Sun appears in the form of electromagnetic radiation. The second part is characterized by dissipation of mass and energy of the high-energy electrons escaping from the positively charged Sun and determines the quasi-constant positive charge of the Sun. The $\alpha_{i1} = 7.5 \cdot 10^{-36}$ parameter for the Sun, like the $\alpha_{i1}$ corresponding value for other stars, determines properties of their corona and properties of the "corpuscles" outflow from the star coronas, i.e., of the positively charged ions. This parameter depends only on the degree of average violation of the star electroneutrality, i.e., total ratio of the number of nucleons with uncompensated charge (protons) by electron charges to the total number of nucleons in the structure. Convective cumulation of low-energy electrons by the positive charge of the Sun in its dynamics leads to their Maxwellization in the Sun region as a result of electron-electron collisions and to generation of small fraction of electrons with enormous energies sufficient to overcome the Coulomb potential of the positively charged Sun. Thus, the Sun space charge is maintained in the dynamics, which is an adiabatic invariant (quasi-constant parameter). The EMPF third part dissipating half of the potential energy (flux cumulating to the Sun) is determined by the accelerated convective scattering from the positively charged Sun of the positively charged ions (protons, alpha particles, etc.), as they are generated in the solar corona or in the heliosphere. Thus, quasi (almost) electrically neutral SW is created from high-energy electrons and positive ions. Energy for the SW outflow is determined by gravitational compression of the Sun in the gravitational field. Compression is accompanied by thermonuclear reactions, discharge of a small part of energetic electrons from the Sun being the most mobile gas, charging the entire Sun to a thousand coulombs and by formation of Coulomb mirrors reflecting the positive ions. This creates a SW from the Sun by establishing enormous (thousand times higher breakdown values) related EF strengths

($E/N \approx$ 26,757 Td and $T_e \sim 2 \cdot 10^6$) at distances of (10–30)$R_S$ and generating fluxes of positively charged ions and of high-energy electrons from the Sun throughout the entire positively charged heliosphere. For all stars, it should be expected that the $E/N$ and the electron temperature would reach maximum values at distances of (10–30)$R_S$ and more of the star radii.

Analysis performed indicates simple interference (interaction) of Coulomb and gravitational forces or potentials in astrophysical objects, which leads to convective corpuscular rotation (energy, mass and pulse vortex structural turbulent plasma exchange, for example, of the Sun with plasma of the entire heliosphere, including ionosphere and charge of the Earth). This cycle (circular global electric current in the heliosphere) is as follows. Hydrogen atoms and molecules around the solar system are focused (cumulated) towards the Sun under the action of gravitational forces. Falling into the region of high $E/N$ values in the solar corona, atoms and hydrogen molecules are ionized by high-energy electrons. Generated protons are accelerated by the EF of the positively charged Sun and dissipate (scatter) from the Sun back into space, where they recombine with electrons and return again to the Sun in the form of hydrogen atoms and molecules. The tremendous velocities of high-energy electrons leaving the Sun and the low velocities of negatively charged dust and low-energy electrons returning to the Sun more slowly result in a small but effective positive charge on the Sun and the heliosphere. Electroneutrality violation and corresponding need to take into account the $\alpha$ parameter, when describing various objects, is caused by the loss of high-energy, mobile and light electrons. It is shown that even weak electroneutrality violation (maintaining quasi-neutrality with an accuracy of 36 signs) in massive plasma structures leads to conditions for separation of part of the structure mass. The process occurs due to the difference in gravitational forces responsible for the structure stability and Coulomb repulsive forces arising from the excessive charge. This contributes to separation of fluxes to the Sun and from the Sun, as well as to separation of charged particles in them according to the $Z/M$ parameter for positive ions and in terms of energies for electrons. Mechanisms that provide the release of heavier ions into interplanetary space than protons and alpha particles and with energies of about $10^3$ eV and more are also understandable. The seemingly insignificant charge of the Sun and the positively charged plasma of heliosphere are responsible for this. Removal from heliosphere occurs for all ions with the charge-to-mass ratio (number of the $M$ nucleons) of $Z/M \geq 0.107$ (6/55.84). At $Z/M < 0.107$, positive ions cumulate to the Sun as a result of gravitational forces and are not observed in the SW. There are no other explanations, why $C^{+4}$

and $O^{+5}$ ions are observed, while the positive $Fe^{+5}$ ion in SW is not observed, as well as all less ionized iron ions. They fly towards the Sun due to the gravity domination for them.

In the case of the plasma structure mass gravitational cumulation, not only the increase in rotation and centrifugal scattering of part of its mass according to the virial theorem [37, 38], but also electroneutrality violation of the entire CD-structure and separation of charged particle fluxes into and out of the structure is taking place [19–21]. Electroneutrality violation causes excitation of the turbulent (vortex, opposite and dual) flows from the structure: high-energy electrons and positive ions with the $Z/M$ value higher than the limiting value, returning flow of low-energy electrons, neutral particles, negatively charged dust and positive ions with the $Z/M$ value lesser than the limiting value determined by effective charge of the entire structure. Consequently, indirect sign of cumulation includes rotation of the structure, its electroneutrality violation and, as a consequence, violation of the first two phenomena, i.e., generation of a magnetic field and of turbulent (vortex) plasma flows around the plasma polarized CD structure. In view of the similar nature of phenomena that could occur in CD structures of any size in micro- and macroworld during EV, the problems being solved are of interest in a wide range of physical problems, including plasma used in practice.

Processes of cumulation of electrons arising in the heliosphere to the surface of the positively charged Sun are responsible for heating the solar corona base to the temperature of $(1.5–2)\cdot 10^3$ K and causing its expansion from the Sun. If they are focused without collisions, then their energy could reach $10^3$ eV. At distances from the Sun of about $(10–20)R_S$, focusing electrons are exposed to inelastic collisions, are Maxwellizing in the electron-electron collisions, and their temperature could be determined by the $E/N$ parameter in accordance with (1). In this case, the average energy of free electrons in this region is about 170 eV (at $E/N \sim 27\cdot 10^3$ Td). In this region, high-energy electrons could change direction and leave the solar system, which leads to cooling the region at $20R_S$ from the Sun.

It is proved that, if the processes of high-energy electrons dissipation are determined by the Maxwellization function of the electron energy distribution, then the positive ion scattering in the form of SW (with trapped electrons) is determined by the Coulomb mirrors action in the EF of the positively charged Sun. In this setting, such phenomena as electric wind, plasma wind and SW are combined into the similar phenomena. These various phenomena are caused by weak electroneutrality violation and significant heating of plasma particles in the EF of a charged structure (charged needle, the Sun, etc.). Cumulative processes on the Sun are determined by gravitational forces, and the corresponding dissipative processes are caused by scattering of the electromagnetic radiation and by “corpuscular rays”, i.e., the SW. High-energy electron scattering from the Sun leads to its positive charge at the level of 1,400 C and cumulation of low-energy electron fluxes and of negatively charged dust towards the Sun. This is how a global electrical circuit is formed in heliosphere. In this global electrical circuit of heliosphere, the Earth ionosphere appears to be only a constituent small part. E. Parker noted [10] that something other than light comes to the Earth from the Sun, and it was stated in 1896 by O.K. Birkeland. He made this conclusion based on the fact that Aurora was very similar to the electrical discharge in the recently invented then tubes generating flows of charged particles (“cathode rays”).

**Conclusion.** It is assumed that the SW mass composition is not changing as it moves in the interplanetary medium and therefore provides information on chemical and ionic composition of the solar atmosphere. Heavy ions are formed in corona, and their state is not changing, when moving in the SW. Consequently, SW ions carry information about conditions in the solar corona. SW observations are of practical importance, since SW plasma is the main agent, by which active processes on the Sun affect the state of near-Earth space and the Earth magnetosphere, and, consequently, weather and well-being of the Earth population. As a result of electron-electron collisions, constant flow of energy arises in the Sun plasma and in its corona into the region of high-energy electrons. This leads to a constant outflow (current) of high-energy electrons escaping from the Sun into space and to the positive charge of the Sun as a whole. This was understood by Eddington in 1926 [1]. Positive charge of the Sun leads to the EF generation, which forms a flow of positive ions from the Sun, and formation of the reverse flow of focusing (cumulating), accelerated by the EF to the positively charged Sun flows of low-energy electrons and negatively charged dust grains from heliosphere and space. Electronic membrane focusing the positively charged plasmoid of any nature is formed in the same way [22, 23]. Failure to take into account the EF caused by the weak (at the level of 36 decimal places) Sun electroneutrality violation and the solar charge at the level of 1,400 C, leads to several asymptotic paradoxes, i.e., discrepancy between experimental observations and incomplete theoretical concepts. (Asymptotic paradoxes, taking into account the highest derivative with a small parameter like the D’Alembert (Euler) paradox, were studied by Oseen, Birhoff, Euler and others [20, 39].) High-energy electrons are absorbed by dust, comets, planets and other particles and charge them with a negative charge. It is believed that the Earth is charged up to 500,000 C [36]. Small positive charge of the Sun remains quasi-constant and is determined by the dynamic distribution of electrons in heliosphere, planets, their satellites, and even in charged dust in the heliosphere. In this regard, for the global electrical circuit, the Sun acts as an anode, and the Earth as a cathode in a huge inhomogeneous discharge with the size of 1 astronomical unit.

On the basis of these ideas about asymptotic paradoxes caused by violation of electroneutrality, as well as experimental studies by the ACE apparatus (2011) of the ion composition of SW [6, 7, 14] and our analytical calculations, for the first time, we proposed and verified by experiments a specific 3D mechanism for heating the SW plasma in the EF of a positively charged Sun. Heliosphere is investigated by us as a CD-structure with dual convective flows (convectively cumulating into a structure and convectively dissipating from the structure). For the first time and as a result of analytical studies of ring current in the heliosphere global electric circuit, the following issues are determined, calculated and verified by observations:

1) positive charge of the Sun is 1,400 C; with such a positive charge, the Sun is able to reflect protons, alpha particles and multiply ionized ions of heavy atoms ($C^{4+}$, $O^{5+}$, $Ne^{8+}$, $Mg^{6+}$, $Si^{6+}$, $Fe^{6+}$, …, $Fe^{12+}$) generated in the solar corona;

2) protons and alpha particles velocities arising at distances from the Sun of $(10–30)R_S$. They are accelerating in EF of the positively charged Sun up to 400 km/s and more in the Earth area;

3) non-compensation coefficient of the Sun positive charge $\alpha_{i1} = 7.5 \cdot 10^{-36}$, i.e., for $10^{36}$ compensated nucleons there are only 7.5 electrons that left the Sun far beyond the problem scope (for example, the Solar system);

4) $E / N$ parameter profile for heliosphere, which determines the breakdown conditions and the electron temperature, the $E(R)$ EF strength profile was calculated according to the Coulomb law, and the profile of nucleon density in heliosphere was taken from [25];

5) the $T_e$ electron temperature profile in the entire heliosphere (from the Sun to the Earth). The $T_e$ profile was calculated using the Nernst — Townsend (Einstein — Smoluchowski) relation for the $E / N$ profile according to (1).

It is proven that the phenomena in heliosphere at distances from $8 \cdot 10^3$ km from the Sun to the Earth and further are similar to the phenomena (ionic or plasma wind) occurring around a sharp charged needle (Franklin's experiments with a rotating wheel, etc.). Studies of phenomena in SW are fully consistent not only with Parker's ideas, to which astrophysicists usually refer, but also with Birkeland, Clausius, Paschen, Stoletov and Townsend views. Clausius introduced the concept of virial in 1870 and showed that only half of potential energy in gravitational and Coulomb fields ($U(r) \sim 1/r$) could be converted into kinetic energy of the focusing EMPF. The fact that half of this energy should be scattered by fluxes dissipating from the structure was reported in [38]. This work develops the ideas of Clausius and Birkeland, who stressed that Auroras are very similar to an electric discharge, to a model based on the ideas of Stoletov and Townsend about importance of the $E/N$ parameter in the gas-discharge plasma phenomena. The proposed model makes it possible to calculate the gas-discharge plasma parameters in the entire heliosphere using the $Z/M$ minimum parameter (6 times ionized iron ion) registered in the SW [14, vol. 1, p. 314]. The model explains the absence of heavy iron ions with lower charge in the SW. Performed analytical analysis of the SW formation causes shows that the indirect indicator of cumulative processes in CD structures of the Sun and Solar System types is not only rotation (E.I. Zababakhin wrote about this [40]), but also electroneutrality violation, magnetic field generation and formation of oppositely directed bicyclic rotating fluxes of the entire mass of the Sun cumulating towards its center and defocusing SW mass leaving the solar system (see [19–21]). Thus, it was proven that SW and Auroras are not only similar, but also are gigantic and laboratory analogs of an electric discharge with different characteristic sizes of a similar class of phenomena described by the Paschen's law.

It was proved by analytical calculations that knowing the SW ionic composition from experiments and according to the method proposed in this work it is possible to calculate electrical parameters of the Sun, its corona and to estimate the energy parameters of ions in the SW in the Earth region. To verify the results obtained detailed experimental studies of the solar corona (particle density profile) and reliable data on the SW ionic composition arising from Coulomb mirrors reflecting these positively charged ions from the Sun are required. Knowledge is also needed on inelastic collisions between nucleons, electron-electron collisions, etc. This knowledge will make it possible to more accurately describe a gigantic inhomogeneous discharge between the positively charged Sun (anode) and negatively charged Earth (cathode rotating around the anode).

When making estimates of the Debye radius and comparing it with the problem scale, astrophysicists often come to a conclusion that EFs are negligible and should not be taken into account. This leads to several asymptotic paradoxes. One of them — the phenomenon of SW and the whole set of accompanying phenomena, we have considered in detail. It is clearly demonstrated that SW is the result of interference (conjugation, interaction, etc.) of gravitational and Coulomb potentials in the inhomogeneous ($N(R) \neq \text{const}$) gas-discharge plasma with current in heliosphere. In gas-discharge plasma of heliosphere or of the Earth ionosphere, the $E/N$ parameter is fundamental, but not $E$ or $N$ separately.

The Debye radius at distances of $(10\text{–}215)R_\text{S}$ does not exceed 1 m. It seemed that EF in the heliosphere could be neglected. However, as we have shown, long-range Coulomb fields at the level of $10^{-8}$ V/cm warms charged plasma particles that do not experience inelastic collisions in the heliosphere to temperatures of a million degrees. It was shown that knowledge of the types of ions in the SW determined in experiments significantly changes calculated parameters of the Sun and, accordingly, parameters of positive ions in the SW under various conditions. The proposed model makes it possible to study new physical mechanisms of SW formation, dynamics of its large-scale perturbations, stratification (as a usual low-pressure discharge observed earlier by Faraday), points, lines and surfaces of libration-cumulation between charged structures in SW, as well as mechanisms regulating the behavior of ionic components with different types of SW flows. Points, lines and surfaces of libration-cumulation between positively charged structures were discovered in the gas-discharge plasma by Vysikaylo [41, 42]. Importance and uniqueness of experimental research in a natural laboratory, i.e., heliosphere, is determined by enormous values of the $E/N$ parameter and by gigantic dimensions of the charged particle accelerator regions with the electron temperatures of up to $2\cdot 10^6$ K. Such parameters could not be obtained in ordinary laboratories, and their study is of great practical and special interest. Such conclusions for stars and other plasmoids follow from correct analysis of the discoveries by Rosseland and Eddington about the “absurdly weak” charge of stars and from ideas by Paschen and Stoletov shown in the Townsend experiments for plasma in the 19th century (more than 130 years ago) on the importance of the $E/N$ parameter, electric field strength related to the particle number density.

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