On accelerative mechanism of nuclear fusion in the Sun

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Abstract. An explanation of an existence of sunspots on the surface of the photosphere is given. They are caused by the presence of current-plasma channels between the surplus negatively charged nucleus and the surplus positively charged photosphere of the Sun. In current-plasma channels and in prominences that appear during electrical breakdown between electric islands on the surface of the photosphere, electrical domains are generated due to presence of runaway electrons. The generation of electrical domains accompanied by the generation of transverse electromagnetic waves. Charged particles in the electromagnetic wave field gain energy that is sufficient to overcome the Coulomb potential barrier.

1. Introduction
According to the existing model the reaction of thermonuclear fusion occurs in the core of the Sun. Astrophysicists have discovered that temperature stars is very high. The solar corona is the hottest element around of the Sun. However there are no reasons to believe that the Sun's core temperature is sufficient for thermonuclear reaction. It is believed that the reaction of thermonuclear fusion takes place in the core of the Sun. The fact that the temperature of the solar photosphere \( T = 5.5 \times 10^3 \, \text{K} \) is many times lower than the temperature of the corona \( T = 2 \times 10^6 \, \text{K} \), which is farther from the core than the photosphere, is still not explained. This fact contradicts the basic laws of thermodynamics and heat transfer. It should be noted that the temperature of the corona is two orders of magnitude lower than the temperature required to overcome the Coulomb potential barrier between the nuclei of the elements. It is possible that the discovered problem of solar neutrino deficiency [1] is not related to the so-called neutrino oscillations. The problem of neutrino deficiency and the fact that the temperature of the corona is much higher than the temperature of the photosphere gives grounds to believe that the mechanism of thermonuclear fusion is not dominant in the Sun. Along with the thermal mechanism of nuclear fusion, other forms of nuclear fusion are also realized. Solar neutrino deficit problem can be explained by the fact that the Sun is not a bunch of high-temperature plasma. The difference between the theoretical assessment of solar neutrino yield and measurements of R.Davis [1] can be explained by the fact that the yield in the reaction can not be determined in result multiplying specific yield by the volume of star. The deficit of electronic neutrino and the fact that the temperature of the solar corona is much higher than the temperature of the photosphere gives reason to believe that nuclear fusion occurs in some areas of the Sun and it does not have a thermonuclear character.

The first experiments to obtain a nuclear fusion reaction were started in 1952. However, such experiments have not yielded positive results to date. A number of problems, such as the anomalous transport of plasma on the walls, the necessity of using a superconducting magnetic system and the
unresolved problem of first wall of the tokamak give reason to believe that the reactor cannot appear in the coming years. The possibility of long-term exploitation of the first wall of fusion reactor at a temperature $T = 10^9 \, K$ in stationary operating conditions and superconducting magnetic system at presence of intense fluxes of radiation also raises to significant doubts [2]. Therefore no reasons to believe, that the transition from a fusion reactor for demonstration to reactor for receiving of energy can be realized formerly than will use to end the reserves of hydrocarbon fuels in the bowels of the Earth. The formulation of the problem of obtaining energy in result of fusion reaction was carried out in the absence of knowledges on the processes that occur in stars. It is therefore necessary to look for simpler and more efficient methods for solving the problem of nuclear fusion, which will make it possible to create reactors with positive energy yield. However, nuclear fusion reaction also takes place inside the Sun as well as in its vicinity - in the solar corona. This is confirmed by the presence of the electron neutrino flux, by a wide spectrum of an intense electromagnetic radiation, by solar flares during increasing of activity and existence of the solar wind in the form of protons. The first experiments on nuclear fusion were performed using accelerators [3]. Many years ago F. Bacon noted that “all the best is in Nature”. Along with thermal mechanism of the nuclear fusion in Nature there are also accelerative mechanism of fusion in plasma and muon-catalyzed fusion. These mechanisms of nuclear fusion exist inside of the Sun and in its vicinity. Therefore it is necessary to use the best that is available in Nature.

The purpose of this paper is to present and analyze several key processes that may be responsible for nuclear fusion inside and around the Sun.

2. A star as an electrical domain of spherical shape

The existing star formation models are unable to explain the high temperature of the star, its rotation and the generation of electric and magnetic fields. It is believed that the star is a clot of high-temperature plasma. The lifetime of plasma is determined by electron-ion recombination in the absence of instability. Plasma may exist for a long time if the recombination is balanced by ionization. However, there are no sufficient grounds to believe that in the presence of a magnetic field in plasma, ionization is balanced by recombination. Laboratory plasma is collisionless ionized gas. As know, stars exist for hundreds of millions of years. For a long time there are also ball lightning, which are formed in electric discharges in the atmosphere of the Earth.

As noted in [4], there is an analogy in the structure of spherically symmetric objects that exist in Nature - ball lightning and stars. Earlier, on the basis of the experimental data obtained in the laboratory, it was shown that the ball lightning has a structure of an electric domain of spherical shape [4-6]. The fact that the ball lightning and the star are electric domains of spherical shape corresponds to the concept of the Electric Universe [7-9]. A number of facts confirm the electrical nature of the Universe. This is not only electrical discharges in the Earth’s atmosphere, but also the phenomena in a rarified atmosphere above earthly thunderstorms as a result of which take place the generation of red sprite, blue glimpses and blue jets. It is known also that a tornado has an electrical nature - electric discharges can raise dust into rotating vertical columns. Electrical activity, including discharges, is also observed in the atmosphere of Venus. Planet Earth also is an element of the global electrical circuit [10]. Explanation for the existence of sunspots and prominences can be given on the basis of the star model as an electrical spherical domain and on the basis of laboratory experiments in the physics of electrical breakdown. The laboratory analogue of prominences can be obtained in the laboratory by a pulsed electrical breakdown between two electrodes – see Figure 1(a).

It is generally accepted that the Sun consists of three main elements: the core, the intermediate layer and the photosphere that surrounds the intermediate layer. The analysis of luminous intensity distribution along the radius of ball lightning allowed to draw a conclusion that higher values of luminous intensity in the external spherical layer are caused by the fact that there are more ions than electrons in the layer [4]. In the central part of ball lightning - into its kernel there are more electrons than ions. The ball lightning consists of a kernel with surplus of negative charge and the external spherical layer with an surplus of positive charge. Between the kernel and the external layer in stars there is an inter-
mediate quasineutral layer. Ball lightning is a structural and electrical analog of a radiating star [4,5,11]. The excess of charges of one sort and the lack of charges of second sort in the kernel or in an external spherical layer significantly reduces the possibility of the electron capture by the nearest ion, therefore the recombination processes in the ball lightning and the star become difficult. A radial electric field exists between the surplus negatively charged solar core and the surplus positively charged photosphere. The presence of this field generates radially directed current-plasma channels. Inside the current-plasma channel there are electrons, and outside - there is an ion layer. The passage of a current creates an azimuthal magnetic field around the channel according to Ampere's law. The exit of electrons to the surface of the photosphere and their spreading over the surface are interpreted by the observers as sunspots. The presence of electrons on the surface of an excessively positively charged photosphere can create electrical islands. Electric domains when approaching the surface of the photosphere can cause prominences of eruptive or fountain types, which are huge fluxes of charged particles.

Figure 1. Integral image of current-plasma channels that appear in an electrical discharge during a breakdown between two electrodes – (a), scheme of the star structure as a spherical electrical domain – (b), and an image of an electrical discharge creating a fluxes of fast particles at passage an electric domain between an electrodes – (b). Designations in (a) and (c): K – cathode; A – anode. Designations in (b): 1 – core; 2 – intermediate quasineutral plasma layer; 3 – external spherical layer (photosphere); 4 – chromosphere; 5 – current-plasma channels with sunspots on photosphere surface.

The second reason for the large lifetime of ball lightning and star consists in that the azimuthal current of charged particles in an external spherical layer or in photosphere creates a poloidal magnetic field (magnetic dynamo) with field lines that are localized in the intermediate layer - see Figure 1 (b). Therefore, the charged particles of the star core and kernel of the ball lightning are situated in the area of minimum of magnetic field induction. Charged particles of the star core or kernel the ball lightning can not move in the radial direction - crosswise magnetic field which increases on radius. The resultant of all forces, including the force of the Coulomb interaction between the elements of a ball lightning or star, force of gas-kinetic pressure and force caused by the centripetal acceleration should be equal to zero in the equatorial plane.

3. Accelerative mechanism of nuclear fusion inside the Sun and around it
In the nearest star to Earth, nuclear fusion occurs both inside and around the Sun: in the chromosphere and in the corona by means of electric domains that are generated in current-plasma channels.
3.1. Nuclear fusion inside a star by means of electric domains generated in current-plasma channels

Due to the presence of “runaway from collisions electrons” in a current-plasma channels appear flat (or elliptical) electrical domains. In the physics of plasma the time of formation of the electric domain is accepted to consider equal to a triple time of Maxwellian relaxation of space charge, i.e. $t = 3\tau_M$. The Maxwellian relaxation time is given by the following expression [12]

$$\tau_M = \frac{\varepsilon}{4\pi \varepsilon_0 n_e \mu_e},$$

(1)

where: $\varepsilon$ is dielectric permittivity and $\mu_e$ is mobility of electrons. It was earlier noted that the nucleation of the electric domains in plasma is accompanied by the generation of transverse electromagnetic waves [5]. The dispersion equation for the transversal electromagnetic waves in plasma which emerge in the process of charge separation is given by the next expression

$$\omega_{sc}^2 = k^2 c^2 + \omega_{sc}^2,$$

(2)

where $\omega_{sc}$ is the frequency of the space charge waves

$$\omega_{sc} = \omega_{pe} + \frac{e}{3im_e \mu_d} = \omega_{pe} - \frac{\omega_{pe}^2}{12\pi \sigma_d} i,$$

(3)

and $\sigma_d$ is a differential conduction of plasma ($\sigma_d = en_d \mu_d$). The equation of motion in general form for the charged particles in a field of a transversal electromagnetic wave is [13]

$$\frac{d (m_\alpha \vec{u}_\alpha)}{dt} = q_\alpha \left( \vec{E}_z + \frac{\vec{u}_\alpha \times \vec{B}_y}{c} \right),$$

(4)

where: $m_\alpha$ is mass of particle, $\alpha$ is sort of particles, $\vec{u}_\alpha$ is velocity of particle, $\vec{E}_z$ and $\vec{B}_y$ are components of the electric and magnetic fields ($\vec{E}_z = E_0 e^{i(\alpha t + \vec{k} \cdot \vec{r})}$; $\vec{B}_y = B_y e^{i(\alpha t + \vec{k} \cdot \vec{r})}$) and $\vec{k}$ is wave vector ($\vec{k} = 2\pi/\lambda$). Ions of deuterium in the field of electromagnetic wave acquire an energy that is enough for overcoming the Coulomb potential barrier and for nuclear fusion [14]. Fluxes of fast particles appear and create turbulence in the Sun plasma. The energy released during nuclear fusion turns into radiation and for supporting of star existence.

3.2. Nuclear fusion during electrical breakdown between two electric islands

Earlier in a number of papers is assumed that the cause of the appearance of prominences is the reconnection of the magnetic field lines. The correct mechanism of reconnection of magnetic field lines is absent. The force lines of poloidal magnetic field outgoing from the star can return to the star only on its opposite side with respect to its equatorial plane. The prominence creates an intense glow. It should be noted that the force line of poloidal magnetic field can not “pull after itself” the flux of particles from the photosphere - this is a delusion. Magnetic field lines cannot come out of sunspots because they are located in the equator area. In this area, the magnetic field lines are perpendicular to the equator plane. Thus, the existence of prominences can only be explained by the presence of electrical breakdown between two regions on the surface of the photosphere with excess charges with opposite signs. Such areas so called an electric islands with excess charges can exist on the surface of the photosphere of the Sun. Electrical breakdown between islands generates in corona the current-plasma channels in the form loop-type prominences, the destruction of which leads to the appearance of plasma clouds. The discharge of such type can be carried out in the laboratory between two electrodes, which are located near the surface of the dielectric.

There is an electric field between two electric islands (clouds, or earth and cloud, etc.). As is known, the initial stage of an electric discharge is called electrical breakdown. The essence of the ele-
tric breakdown mechanism is due to the appearance of an electric domain with a strong field in the near-electrode region [15]. An increase in the electric field strength (due to amplification on inhomogeneities or due to the appearance of fast particles in the spectrum of cosmic radiation or when a high voltage pulse is applied) causes the displacement of a group of charged particles from particles of another kind by exceeding the Debye screening length. Due to the separation of charges, an electric domain with a strong field appears in the near-electrode region, the generation of which is accompanied by the appearance of a transverse electromagnetic wave [5,16]. Charged plasma particles from the breakdown region, as well as ions that are in the field of the transverse electromagnetic wave, will gain energy that is much higher than the energy that is needed to overcome the Coulomb potential barrier. The electric domain is always at the head part of the current-plasma channel moving in space between an electrodes or clouds. The corona is heated due to the energy released during the fusion of nuclei. Figure 1(a) shows the current-plasma channels, which are formed during an electrical breakdown between two electrodes on experimental setup “Prometheus”. In these experiments, the anode had the ability to move relative to the cathode, which had a high voltage (15 kV). The maximum height of current-plasma channels during breakdown in air was equal to 50 cm. The discharge glow was recorded by a camera with an open shutter. The presence of accelerated particles was detected by a collector, and their energy was detected by their range in aluminum foils of known thickness. The maximum particle energy was equal to 100 keV. Charged particles gained energy in the field of a transverse electromagnetic wave, which is formed during electrical breakdown during the generation of electrical domains. Captured and accelerated fluxes of fast particles at an electrical breakdown between two electrodes in the form of jets are shown in Figure 1 (c). The discharge glow was recorded by a high-speed camera “Fast-Cam-5”.

3.3. Other acceleration mechanisms
Interesting phenomena occur when the diameter of sunspots changes or when they approach each other [17]. Changes in the diameter of the sunspot leads to changes of the magnetic flux, which is accompanied by an increase in potential in accordance with Faraday's law and, consequently, to a significant increase in the energy of charged particles.

Very often sunspot pairs have opposite magnetic polarity. Therefore, they are approach to each other and merge at a later time. The movement of sunspots with opposite magnetic polarity also leads to the generation of an electric field by which charged particles can be accelerated. These mechanisms are considered in more detail in [17].

4. Conclusion
The model of a star on the basis of electric domain of the spherical form which allows to explain existence of sunspots is developed. The sunspots are explained by the output of electrons to the surface of the photosphere from the current-plasma channels. In current-plasma channels and at electrical breakdown between electrical islands on the surface of the photosphere there are flat (or semi-elliptic) electrical domains. Domain generation is accompanied by the generation of transverse electromagnetic waves, in the field of which ions and protons gain energy that is sufficient to overcome the Coulomb potential barrier and nuclear fusion. The accelerative mechanism based on the separation of charges was developed in [18]. Further development of accelerative mechanism will make it possible to create an intensive neutron source.

Advances in experiments on generation of ball lightning in the laboratory [4,5,11] allowed to explain the structure of the star as an electric domain of spherical shape [19,20]. It should be noted that in [21] a promising method of muon catalyzed fusion was proposed, which is based on the ball lightning injections into low-temperature plasma. Following F.Bekon it is necessary to use all the best that is available in Nature. To solve the problem of nuclear fusion, it is necessary to develop new effective methods, which is an alternative to existing which do not give a positive solution.

This and other research of author did not receive any specific grant or financial support from funding agencies in the state, public, commercial or not-for-profit sectors.
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