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New Aeroion Model of a Dangerous Natural Phenomenon—Ball Lightning

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Abstract

Today a natural ball lightning (BL) phenomenon has not yet correct physical and philosophical explanation. This article is directed on a new exotic version of the occurrence and behavior of ball lightning. BL consists of a bulk air mixture—neutral air molecules, negative and positive aero ions. BL arise on linear lightning tracks due to the primary ionization of the atmosphere and the secondary effects of atmospheric light aero ions arisen. The emerging electrostatic surface tension forces form a volumetric gas drop, in which the significant electrical energy of the "ball capacitor" is concentrated. The long lifetime of aero ions provides time stability of gas ball. As a rule, a BL gradually discharges and disappears due to recombination processes, emitting a weak cold glow. The explosion of BL occurs with an external destabilizing effect on its structure. First of all, this is contact with a source of free electrons—any conductive objects and surfaces, including the human body. The impulse powerful discharge of "ball capacitor" is very dangerous for human. Some other properties of BL are also discussing in this philosophical note.

Keywords

Ball Lightning, Light Aero Ions, Surface Tension Forces, Volume Electrical Capacitor, Aero Ion Lifetime, Cold Glow, Explosion, Human Security, High-Temperature Plasmoids, Linear Lightning, Volumetric Explosion, Avalanche Air Ionization

1. Introduction

"There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy"—the great phrase of Hamlet, created by the genius of Shakespeare, also applies to a large number of natural phenomena that have not yet received physical and other explanations, therefore, continue to excite the scientific community. Among such phenomena is ball lightning (BL). Hundreds of observations and thousands of scientific publications have been devoted to this phenomenon since 1195. Materials on the history, description of properties and characteristics, as well as the main scientific and near-scientific theories on the occurrence of BL, are quite fully given in review articles: https://en.wikipedia.org/wiki/Ball_lightning and (Stakhanov, 1985) Most of the models are attempts to explain the appearance and long-term existence of high-temperature plasmoids in the atmosphere, enclosed in their own or external magnetic and microwave fields (Galanin, 2014), (Averin, 2005), (Phedosin & Kim, 2000). One of the contradictions of these hypotheses is that BL sometimes lives for several minutes, and at an estimated temperature of 10,000 - 15,000 degrees, the kinetic energy of plasma particles becomes greater than the forces of their electrical interaction, and BL should instantly fall apart. Attempts to explain the stability of BL by external energy electromagnetic replenishment, for example, by the P.L. Kapitza (Kapitsa, 1955) are not substantiated yet and are also contradictory. One of the many typical examples of BL behavior is given below: "I saw at a distance of about 10m that a ball lightning of light yellow color with a diameter of 30 - 40 cm jumped out of the ground at the site of an ordinary lightning strike. Having risen to a height of 6 - 8 meters, it began to move horizontally. At the same time, it pulsated, taking either a spherical or an ellipsoidal shape. After walking a distance of about 50 m in 1 minute, BL stumbled upon a pine tree and exploded". It should be noted that the color of the BL can indeed turn red, then yellow, then white, then blue. It is often accompanied by a hissing sound and a distinct smell. The phrase: "jumped out of the ground at the place of an ordinary lightning strike", gives the closest description of the color of the BL. At the place of the "strike" of linear lightning into the ground, the temperature can reach several thousand degrees, which leads to the appearance of soil chemical elements in the BL, as well as chemical pollution existing in a thunderstorm atmosphere. The rare phenomenon of BL has not allowed, so far, carrying out systematic experimental studies of this phenomenon. In works (Cen et al., 2014) and (Ball Philip, 2014), randomly obtained energy spectra are given, also of a BL that "flew out of the earth" at the site of a "strike" of a linear lightning. These spectra contain both understandable oxygen and nitrogen recombination spectra and silicon spectra, which is consistent with their "impact" terrestrial origin. It should be noted that there are many negative reviews in the comments on these instrumental observations using a high-speed video camera. It seemed that a promising way to study the process is the experimental creation of BL in the laboratory. Recently, several statements have been made about the production of artificial ball lightning, but even these statements in the academic environment have developed a skeptical attitude. The main question is whether the phenomena observed under laboratory conditions are really identical to natural ball lightning (Ohtsuki & Ofuruton, 1991) and (Sakawa et al., 2006) The experimental observations of the so-called cold plasmoids and black BL (Dmitriev, 2011) are very interesting for this publication, in which cluster models of low-temperature plasmoids are proposed, consisting of ionized air molecules surrounded by solvate (hydrate) shells, the so-called "thunderstorm substance" similar in properties to plasma. In favor of the low-temperature nature of the BL is the experimental fact that the BL does not emit significant thermal energy and glows like a conventional 100W light bulb. At the same time, a BL explosion has a significant power. Most of the accumulated energy is released for a short time (ms), which leads to the melting of the metal at the place of the "impact", the burning of trees, etc., and is misunderstood as a high temperature inside the BL itself.

2. Formation and Behavior of Light and Heavy Aero Ions during Avalanche Air Ionization

The ball lightning observed by people occurs, as a rule, during a lightning discharge between clouds and the earth. Such downward lightning, being an atmospheric spark electric discharge of tens of thousands and hundreds of thousands of amperes at voltages of tens and hundreds of millions of volts, develops in several stages, and the physics of these processes is well studied. **Figure 1** shows a photo of a typical lightning on the left, and a photo of its ideal linear discharge (LM) on the right.

Next, we will consider the ideal discharge (on the right) and the ionization it produces in the air, which is the main factor in the initiation and development of linear and ball lightning. An approximate cross-section of the LM is shown in **Figure 2**. Its main channel can be units—tens of centimeters—and the time of a full lightning discharge can reach several seconds. The main channel is surrounded by areas of dense air ionization, which initially range in size from tens of centimeters to a meter or more. The degree of air ionization in these areas reaches millions of ions/sm^2 and is provided mainly by avalanche (shock) reproduction of secondary electrons in strong electric fields. Due to the resulting explosive (thermal) wave, these areas expand at an average speed of 1000 m/s. The concentration of particles in the shock wave increases by about 8 - 10 times compared to the average concentration in the normal atmosphere, and the air temperature sharply decreases with distance and time. Under normal conditions, the composition of air is illustrated in **Figure 3**. It should be noted that in the

Figure 1. Photographs of a typical (left) and ideal (right) linear lightning (LM).

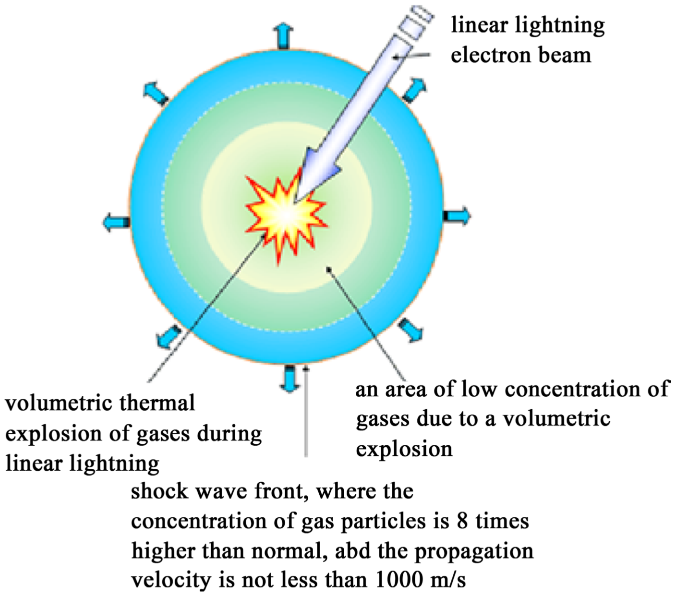

Figure 2. Model of the cross-section of the LM during a volumetric thermal gas explosion.

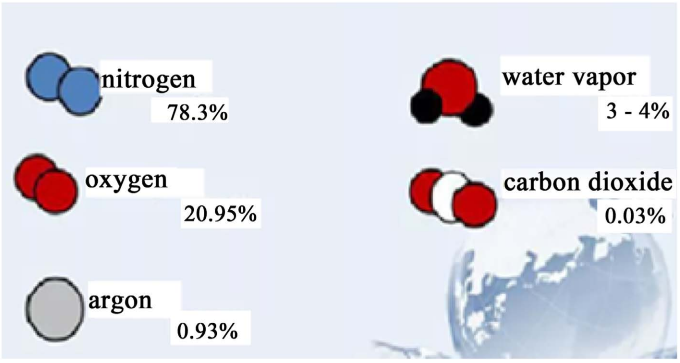

Figure 3. The main composition of atmospheric air.

proposed model, when passing through the LM, regions of dense ionization appear almost instantly (fractions of milliseconds), consisting of positive ions of nitrogen, oxygen, and free electrons.

With the expansion of dense ionization regions, free electrons: 1) having high mobility in an electric field (thousands of times greater than ionic mobility), "scatter" from the volume due to strong magnetic and electromagnetic fields of a lightning discharge and thermalization; 2) recombine with positive ions, creating electromagnetic radiation; 3) upon reaching the molecular temperature, several hundred degrees (more than 100˚C) "stick" to neutral air molecules, creating stable negative light aero ions. At the same time, positive aero ions appear on positive ions and molecules (nitrogen, carbon dioxide). Aero ions with a negative charge are formed mainly from oxygen molecules, tending to attach additional electrons and gain stability. Aero ions with a negative charge are formed mainly from oxygen molecules, tending to attach additional electrons and gain stability. A positive charge is obtained, as a rule, by carbon dioxide molecules that lose a valence electron. The attachment ("sticking") of an electron to a neutral molecule leads to such a rearrangement of its electron shell that, as a result, the energy of the molecule that has captured the extra electron turns out to be less than the energy of the neutral molecule by a certain value, which is called the "electron affinity energy" (EAE). It fluctuates for most atmospheric gases from 0.75 - 4.5 eV. In inert gases - in argon, neon, helium, krypton, xenon, as well as in nitrogen, negative aero - ions do not arise. But, a molecule, where one electron is missing, after 10^{-7} seconds, attaches 4 - 12 neutral polar molecules to itself, forming a light positive ionic cluster. An important feature of light negative "oxygen" aero ions is their lifetime, which can be up to 10 minutes. This feature makes it possible, for example, to remotely register alpha particles with a high-voltage discharge detector open to the air (Gurkovskiy et al., 2015). Aero ions are conditionally divided into three groups according to their mobility in electric fields:

- light, with a speed of movement in an electric field from 1 to 2 sq.cm/V*s consist of several dipole molecules surrounding charged aero ions
- medium, a speed 0.02 - 0.01 sq.cm/V*s consist of complexes of light aero ions settled on liquid or solid components of air;
- heavy, these are aero ions with a speed of 0.0005 sq.cm/V*s, they are found in fog, raindrops, smoke, soot.

The main role in the creation of BL is played by light aero ions, primarily long-lived negative aero ions of oxygen and positive nitrogen ions, surrounded by dipole molecules of water and other gaseous air components.

3. Aero Ionic Model of the Occurrence and Behavior of Ball Lightning

According to the proposed model, during the passage of a lightning discharge, cylindrical regions of high air ionization are created around the main channel. It should be noted that the same regions also appear on the trajectories of lightning leaders. These initially high-temperature plasma regions, in the process of and after the passage of the main discharge, are exposed to powerful electromagnetic and quasi-static electric fields, a thermal volumetric explosion. They expand in space, their volume increases, the temperature decreases. Moreover, since the temperature of the electrons is thousands of times higher than the ionic and molecular temperatures, the electrons leave these regions and scatter into the surrounding space. The process of secondary electron ionization gives way to recombination processes, which primarily produce light radiation. Finally, thermal ionization also gives way to the attachment of electrons to neutral molecules (oxygen)—the creation of negative light aero ions, to which positive nitrogen ions are attached. Positive aero ions, such as carbon dioxide, are enveloped by dipole molecules, such as oxygen and water. Thus, in the post-thunderstorm space, new electrically neutral regions appear, consisting of neutral air molecules, negative and positive aero ions, with the practical absence of free electrons. This form of gaseous aero ionic plasma was called "thunderstorm matter". A certain ratio of the components of this substance in a closed volume leads to the effect of a drop-formation in a gaseous medium. As in water, the emerging surface tension forces (due to aero ions electrostatics) form a ball lightning drop, which both in volume and on the surface contains stable aero ionic complexes. A simplified structure of such a ball is shown in **Figure 4**. The building blocks are electronegative aero ions of oxygen, which have the greatest temporal stability in a normal atmosphere, as well as electropositive aero ion complexes based on nitrogen ions, carbon dioxide, etc. The question regarding at what concentration of aero ions the creation of a gas-air drop begins, requires additional research.

In terms of radiation characteristics, BL is similar to a glow gas discharge, the recombination radiation of which occurs at temperatures of several hundred degrees Celsius and is maintained by an external current. Aero ionic plasma of BL radiates its energy accumulated in aero ions by the same recombination processes of charge exchange between aero ions, as well as interactions with free electrons entering it. The discharge of a natural bulk capacitor occurs with different time constants, depending on the nature of the appearance and breaking of electron-atomic, as a rule, covalent bonds in aero ions complexes, and lasts from fractions of seconds to 1000 seconds, which corresponds to the average time ranges of the BL life under undisturbed conditions. The size, volume of the BL corresponds to the accumulated charge and energy. Attempts to calculate these values using the electrical formulas of a spherical capacitor, in my opinion, are not correct, due to the difference in the physic-chemical mechanism of charge accumulation for different BL models. The condition for the existence of quasi-neutral plasma is a certain maximum density of charged particles. This density is determined in plasma physics from the inequality $L \gg D$, where D is the so-called Debye screening radius, which is the distance at which the Coulomb field of any plasma charge is screened. The plasma quasi-neutrality condition - the linear dimensions - of the plasma should significantly exceed: $L \gg D$. However, the Debye screening radius for aero ion plasma is not known, which also requires an additional experimental-theoretical evaluation of this value. Visual observations of BL show that its dimensions vary from a few to tens of centimeters. At smaller sizes, BL are not born, or they are instantly discharged, and at large ones, the necessary density and volume neutrality of aero ionic charges are not provided. In any case, the formation of BL and its long existence is a probabilistic process, which limits the possibilities of its instrumental experimental studies. As noted above, recombination processes in BL lead to a cold glow, mainly in the visible spectrum of electromagnetic radiation, a gradual discharge and disappearance of BL. In this case, the color of BL may change depending on its complex composition, including inert air gases, its organic and inorganic pollution. An example of the silicon emission spectrum associated with the contamination of BL during a linear lightning strike into the ground, is given above. The BL structure, consisting of a mixture of relatively stable (oxygen, electron affinity is +1.467 eV) and unstable (nitrogen, −0.21 eV) aero ions, begins to decay faster under external energy influences. Moreover, the power of an external influence, for example, an electromagnetic pulse of a continuing thunderstorm, or a microwave signal of communication devices, either accelerates the discharge of BL, or leads to a chain reaction of decay of aero ions in the form of an “accidental” explosion. The same effect accompanies the contact of the BL with a source of free electrons. If the flow of electrons in the BL that occurs in this case is limited, then an electric discharge occurs, which, by the way, is dangerous for humans. If the flow is not limited, then an explosive discharge of BL (similar to a short circuit in an electrical network) is possible, with dangerous thermal and electrical consequences. The power of such an explosion essentially depends on the discharge time and the amount of “thunderstorm substance” involved in this process. According to eyewitnesses, the BL explosion ranges from a loud bang to the destruction of residential structures and a fire. For human life (cardiac fibrillation), the most dangerous are the industrial currents (50-60Hz), however, large lightning currents can lead to fatal thermal damage to human tissues. It is empirically clear that the density of BL does not differ much from the density of the atmosphere. According to a number of models, the BL density is a fraction and a few percent higher than the density of the surrounding atmosphere (Grigor’ev, et al., 2016). BL floats in the air like a balloon. The electrical nature of BL leads to its interaction with external electric and magnetic fields. The BL either attracts or repels charged objects, moves not only in air flow, but also along the lines of force of magnetic and electric fields. External fields and thermal processes inside the BL lead to the ejection of its matter to the outside, luminous “prominences” appear. The forces of gravity and atmospheric resistance can change the traditional spherical shape of the BL to an ellipsoidal one, etc. An extraordinary property of BL is its observed passage through dielectric glass with the formation of a hole even at the edges. Original explanations of this phenomenon have been proposed in the literature (Miskinova & Shvilkin, 2015). However, in my opinion, this process is due to the low-temperature electrochemical reaction of glass dissolution in an efficient BL ionic chemical reactor. Moreover, as was shown, the atoms of the main component of simple glass (SiO_2) are well integrated into the aero -ionic structure of BL.

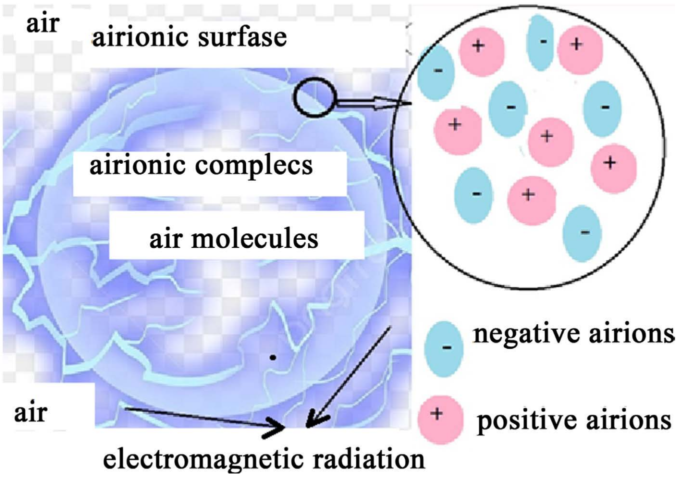

Figure 4. Simplified block diagram of a BL drop.

4. Conclusion

The paper suggests that ball lightning is formed in the volume of a secondary gaseous low-temperature aero ionic plasma, the so-called “thunderstorm substance”, consisting of neutral air molecules, negative and positive aero ions in the absence of free electrons. Aero ionic plasma is a product of the transformation of the original high-temperature electron-ionic plasma that arises around and in the linear lightning channel itself. Thermal volumetric explosion, electromagnetic and thermal scattering of electrons from ion-electron plasma, in combination with a falling temperature and reaching a certain density of aero ions of both signs, leads to the appearance in air (inherent in liquids) of short-range electron-chemical bonds of aero ions and the appearance of surface tension forces. These forces form a BL drop, the size of which, as well as the density of particles charged in it (according to the principles of plasma physics), cannot be less or more than certain values. Really observed sizes of BL vary from a few to tens of centimeters, and the density does not exceed by several percent the density of the surrounding atmosphere. Recombination of aero ions creates cold visible radiation of BL. Its color can be changed by various types of BL pollution. The temporal scatter of the discharge of various aero ion clusters in the absence of external destabilizing factors leads to a scatter in the lifetime of the BL itself. Being a gas ball made up of differently charged particles, BL is exposed to external electromagnetic fields, which can lead to changes in its movement, acceleration of internal processes of the collapse of aero ions-slow extinction or “accidental” explosion. Contact with sources of free electrons, which accelerate the electronic recombination of aero ions, leads to the early “death” of BL. If the flow of electrons is limited, this causes the discharge of the BL with an external current, the impulse of which can be dangerous for a person. If the electron current is not limited, it causes, as a rule, an explosive process with shock air and electrical consequences. Some exotic properties of BL, such as the burning of even holes in thin glass, are explained by the electrochemical dissolution of a dielectric in active aero ion plasma. The emergence and life of BL is a random process that depends on many factors. Therefore, BL is a unique natural phenomenon that is still inaccessible for system instrumental researches.

This article offers one of the possible explanations for the nature and behavior of the BL phenomenon and is aimed at developing scientific research in this direction. In particulate, the results may be used for developments of new techniques for experimental creation of artificial BL and them researches.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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