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High-Energy Atmospheric Physics: Ball Lightning

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Abstract

This article proposes an explanation for High-Energy Atmospheric phenomena through the frames of Hypersphere World-Universe Model (WUM). In WUM, Terrestrial Gamma-Ray Flashes (TGFs) are, in fact, Gamma-Ray Bursts (GRBs). The spectra of TGFs at very high energies are explained by Dark Matter particles annihilation in Geocorona. Lightning initiation problem is solved by GRBs that slam into thunderclouds and carve a conductive path through a thunderstorm. We introduce Multiworld consisting of Macro-World, Large-World, Small-World, and Micro-World, characterized by suggested Gravitational, Extremely-Weak, Super-Weak, and Weak interaction respectively. We propose a new model of Ball Lightning formation based on the Dark Matter Core surrounded by electron-positron plasma in the Small-World.

Keywords

Hypersphere World-Universe Model, High-Energy Atmospheric Physics, Ball Lightning, Geocorona, Lightning Initiation Problem, Terrestrial Gamma-Ray Flashes, Gamma-Ray Bursts, Dark Matter Core, Electron-Positron Plasma, Multiworld

1. Introduction

This paper is based on the revised World-Universe Model (WUM) [1]. To be consistent with the Law of Conservation of Angular Momentum, WUM is modified as follows:

- New Dark Matter particles, named Dions, with mass 0.2 eV and energy density of 68.8% of the total energy density of the World compose outer shells of Supercluster's Cores. They are responsible for the Le Sage's mechanism of the gravitation [2];

- Proposed force of Weak Interaction between Dark Matter Particles (DMPs) provides the integrity of Dark Matter Cores of all Macroobjects;
- The origin of the Solar corona plasma is the result of the annihilation of DMPs with mass 1.3 TeV. The Solar corona made up of DMPs resembles a honeycomb filled with plasma;
- The composition and characteristics of Geocorona and Planetary Coronas are similar to those of the Solar Corona.

In the present article we develop a new Model of High-Energy Atmospheric Physics based on the approach to Geocorona suggested by WUM [1]. To explain the formation of Ball Lightnings and their characteristics we introduce the Small-World characterized by the proposed Super-Weak interaction between DMPs. We calculate main parameters of different Worlds in the suggested Multiworld.

In Section 2 we present a short history of Ball Lightning hypothesis. In Section 3 we present experimental results and existing theories in High-Energy Atmospheric Physics concerning Lightning initiation problem and Terrestrial Gamma-Ray Flashes (TGFs). In Section 4 we provide a short description of the Geocorona model and propose that TGFs are, in fact, Gamma-Ray Bursts (GRBs). Spectra of TGFs at very high energies are produced by DMPs annihilation in Geocorona. Lightning initiation problem is solved by GRBs that slam into the thunderclouds. In Section 5 we introduce Multiworld consisting of Macro-World, Large-World, Small-World, and Micro-World characterized by proposed Gravitational, Extremely-Weak, Super-Weak, and Weak interaction respectively. In Section 6 we propose a new model of Ball Lightning formation based on the Dark Matter (DM) Core surrounded by electron-positron plasma in the Small-World.

2. Short History of Ball Lightning Hypothesis

Ball lightning is an unexplained atmospheric phenomenon that is usually associated with thunderstorms and lasts considerably longer than the split-second flash of a lightning bolt. Ball Lightning (BL) usually appears during thunderstorms, sometimes within a few seconds of lightning, but sometimes without apparent connection to a lightning bolt. In some cases, BL appears after a thunderstorm—or even before it. In 1972, Neil Charman published a review in which he identified the properties of a "typical" BL [3]:

- They frequently appear almost simultaneously with cloud-to-ground lightning discharge;
- They are generally spherical or pear-shaped with fuzzy edges;
- Their diameters range from 1 cm to several meters, most commonly 10 - 20 cm;
- They can be seen clearly in daylight;
- The lifetime of each event is from 1 second to over a minute with the brightness remaining fairly constant during that time;
- They tend to move, most often in a horizontal direction at a few meters per

second, but may also move vertically, remain stationary or wander erratically;
- Many of them are described as having rotational motion;
- It is rare that observers report the sensation of heat, although in some cases the disappearance of the ball is accompanied by the liberation of heat;
- Some display an affinity for metal objects and may move along conductors such as wires;
- Some appear within buildings passing through closed doors and windows;
- Some have appeared within metal aircraft and have entered and left without causing damage;
- The disappearance of a ball is generally rapid and may be either silent or explosive.

Vacuum hypothesis: An attempt to explain ball lightning was made by Nikola Tesla in 1904 [4], but there is at present no widely accepted explanation for the phenomenon. Tesla's thoughts on BL production are presented in a review "Tesla and Ball Lightning" [5]:

When sudden and very powerful discharges pass through the air, the tremendous expansion of some portions of the latter and subsequent rapid cooling and condensation gives rise to the creation of partial vacua in the places of greatest development of heat. These vacuous spaces, owing to the properties of the gas, are most likely to assume the shape of hollow spheres when, upon cooling, the air from all around rushes in to fill the cavity created by the explosive dilatation and subsequent contraction.

Suppose now that this result would have been produced by one spark or streamer discharge and that now a second discharge, and possible many more, follows in the path of the first. What will happen? Let us now assume that such a powerful streamer or spark discharge, in its passage through the air, happens to come upon vacuous sphere or space formed in the manner described. This space, containing gas highly rarefied, may be just in the act of contracting, at any rate, the intense current, passing through the rarefied gas suddenly raises the same to an extremely high temperature, all the higher as the mass of the gas is very small.

Tesla considers that the initial energy of the nucleus is not sufficient to maintain the fireball, but that there must be an external source of energy. According to Tesla, "*this energy comes from other lightnings passing through the nucleus*", and the concentration of energy occurs because of the resistance of the nucleus, *i.e.* the greater energy-absorbing capacity of the rarefied gas than the surrounding gas through which the discharge passes [5].

Microwave cavity hypothesis: Peter Kapitsa proposed that BL is a glow discharge driven by microwave radiation that is guided to the ball along lines of ionized air from lightning clouds where it is produced. The ball serves as a resonant microwave cavity, automatically adjusting its radius to the wavelength of the microwave radiation so that resonance is maintained [6].

Maser-Soliton hypothesis was proposed by Peter H. Handel in 1975 [7]. Ac-

cording to this hypothesis, outdoor BL is caused by an atmospheric maser—analogous to a laser but operating at a much lower energy—having a volume of the order of many cubic kilometers.

Antimatter hypothesis: In 1971, fragments of antimatter comets or meteoroids were hypothesized, by David Ashby and Colin Whitehead, as a possible cause for BL [8]. They monitored the sky with gamma-ray detection apparatus and reported unusual surges of radiation at 511 keV, which is the characteristic gamma ray frequency of a collision between an electron and a positron. The authors noted that there were no thunderstorms present at the times that the gamma-ray readings were observed. They proposed that BL was caused by tiny grains of antimatter. These grains arrived from space and slowly filtered down through the Earth's atmosphere, shielded from immediate annihilation by a kind of quantum barrier. The grains would tend to become negatively charged through the emission of positrons and so would be drawn to the ground as it became positively charged during thunderstorms [9].

Scientists using NASA's Fermi Gamma-ray Space Telescope have detected beams of antimatter produced above thunderstorms on Earth, a phenomenon never seen before. Members of Fermi's team think the antimatter particles were formed in a TGF, a brief burst produced inside thunderstorms and shown to be associated with lightning. They have detected gamma rays with energies of 511 keV [10].

Black hole hypothesis: Another hypothesis is that some BL is the passage of microscopic primordial black holes through the Earth's atmosphere. This possibility was mentioned in a patent application in 1996 by Leendert Vuyk [11]:

A reactor chamber for containing and exploiting ball lightning discharges consists of vessels with a symmetrical axis and a mating surface perpendicular to the axis. Also claimed is a method for containing, developing and exploiting two black holes or ball lightning discharges using the chamber described above. The two black holes are placed in one part of the vessel following which the vessel is sealed to the second part.

The first detailed scientific analysis of this hypothesis was made by Mario Rabinowitz in 1999 [12]: *Small, quiescent black holes can be considered as candidates for the missing dark matter of the universe, and as the core energy source of ball lightning. By means of gravitational tunneling, directed radiation is emitted from black holes in a process much attenuated from that of Hawking radiation which has proven elusive to detect. Gravitational tunneling emission is similar to electric field emission of electrons from a metal in that a second body is involved which lowers the barrier and gives the barrier a finite rather than infinite width. Hawking deals with a single isolated black hole.*

Extreme Ball Lightning hypothesis: Van Devender distinguished Extreme Ball Lightning (EBL) from ordinary Ball Lightning (BL) by the following characteristics [13]:

- It glows in air;

- It originates from nothing visible;
- It lasts between 10 and 1200 seconds;
- It is lethal or potentially lethal;
- It causes significant damage;
- It contains energy estimated at 100,000 to 1 billion Joules, far in excess of the energy density attributable to chemicals or electrostatics;
- It penetrates walls, glass and metal, generally without leaving a hole;
- It leaves black streaks on corpses without the spasm of electrocution;
- It can excavate tons of earth.

According to Van Devender, to date no theory addresses the characteristics of EBL. He said, "*It seems to require new physics*" [14].

In view of Wal Thornhill, explaining EBL doesn't require new physics. The clue of his hypothesis comes from the observed ability of EBL to penetrate solid material. According to Thornhill, there is one stable particle that has the ability to pass through solids without any appreciable effect—neutrino, which in the presence of an excited nucleus may accept a lower level of energy than required for pair production and form a stable "heavy neutrino" [13].

Microwave Bubble hypothesis: H.-C. Wu proposed the following explanation of a formation of BL:

- A relativistic electron bunch can be produced by the stepped leader of lightning and coherently emit high-power microwave when striking the ground;
- The intense microwave ionizes the local air and evacuates the resulting plasma by its radiation pressure, thereby forming a spherical plasma cavity that traps the microwave [15].

Observation of the Optical and Spectral Characteristics of Ball Lightning was made by Jianyong Cen, *et al.* in 2012 [16]. At a distance of 900 m a total of 1.64 seconds of digital video of the BL and its spectrum was obtained, from the formation of the BL after the ordinary lightning struck the ground, up to the optical decay of the phenomenon. The BL traveled horizontally across the video frame at an average speed of 8.6 m/s. It had a diameter of 5 m.

Oscillations in the light intensity and in the oxygen and nitrogen emission at a frequency of 100 Hz, possibly caused by the electromagnetic field of the 50 Hz high-voltage power transmission line in the vicinity, were observed. From the spectrum, the temperature of the BL was assessed as being lower than the temperature of the parent lightning (<15,000 - 30,000 K). The observed data are consistent with vaporization of soil as well as with ball lightning's sensitivity to electric fields [16].

3. High-Energy Atmospheric Physics

In his "the mystery of Lightning" review [17], a leading lightning physicist Joseph R. Dwyer provides an excellent overview of the main experimental observations and leading models of thunderstorms and lightnings. Many mysteries re-

main about how thunderstorms and lightnings work, including how lightnings get started. It is established that thunderstorms and lightnings produce intense bursts of x-rays and gamma-rays. These high-energy radiations may be important for understanding how lightning works.

Lightning initiation problem: Years of balloon, aircraft, and rocket observations have never found large enough electric fields inside thunderstorms to make a spark. And yet lightnings strike the Earth about 4 million times per day. This has led to the cosmic-ray model of lightning initiation [17]:

- Cosmic ray slams into atmosphere and carves a conductive path through a thunderstorm;
- Air showers alone will not increase the conductivity enough to initiate lightning;
- A mechanism of runaway electron avalanche was proposed in order to increase ionization [18];
- Strong electric fields accelerate electrons to nearly the speed of light;
- These electrons emit x-rays and gamma-rays, which were observed by G. Fishman, *et al.* [19];
- A gamma-ray flash descends from the overhead thundercloud;
- It is not clear why some discharges make x-rays and others do not;
- Gamma-rays are produced inside of thunderstorms;
- Explosive production of energetic particles were observed from space [19];
- Thunderstorms create electron and positron beams;
- Thunderstorms produce Terrestrial Gamma-ray Flashes (TGFs).

Terrestrial Gamma-Ray Flashes were first detected by chance by NASA's Earth-orbiting Compton gamma ray telescope. Compton was searching for GRBs from exploding stars, when it unexpectedly began detecting very strong bursts of high energy x-rays and gamma rays, coming from Earth. Detectors observed an unexplained terrestrial phenomenon: brief (lasting about a millisecond), intense flashes of gamma rays. According to G. J. Fishman, *et al.*, "*These flashes must originate in the atmosphere at altitudes above at least 30 kilometers in order to escape atmospheric absorption and reach the orbiting detectors. The photon spectra from the events are very hard* (*peaking in the high-energy portion of the spectrum*) *and are consistent with bremsstrahlung emission from energetic MeV electrons. The most likely origin of these high-energy electrons, although speculative at this time, is a rare type of high-altitude electrical discharge above thunderstorm regions*" [19].

A paper by Joseph R. Dwyer, *et al.* provides a brief review of TGFs [20]: "*They have durations ranging from a few tens of microseconds to a few milliseconds* [21] [22] *and produce the highest energy emission of natural phenomena originating from within the Earth's atmosphere* [23] [24] [25]. *TGFs are relatively common, with a thousand or more produced around the planet each day* [22], [26]. *Spacecraft measurements have found that the source altitudes of the gamma rays must be below* 20 *km* [23] [27] [28] [29], *within the altitude range of thunderstorms. The spectra of TGFs* (*up to a few tens of MeV*) *are consistent with bremsstrahlung emissions from energetic electrons accelerated by strong*

electric fields within the thunderclouds [23] [27] [28], *although there is currently some debate about the spectra at very high energies* (~40 - 100 *MeV*) [24] [30]. *It is a challenge to develop models that can explain how large numbers of high-energy electrons are generated so rapidly deep within the atmosphere* [31]".

There are two leading models of TGF formation [17]:

1) Lightning leader emission, similar to x-ray emission seen near the ground;

2) Dark Lightning, which:

- Generates so many high-energy particles that it discharges the thunderstorm faster than normal lightning;
- Makes currents > 100,000 amps;
- Emits very little visible light, *i.e.* appears dark;
- Can explain TGFs;
- Cosmic rays are not needed.

But how can we explain a new mystery: A bright TGF was seen by spacecraft in the middle of Sahara Desert on a nice day. The nearest thunderstorms were ~1000 miles away [19].

4. Geocorona

Let's summarize the obtained results, which are difficult to explain in frames of the existing models:

- Sometimes BL appears without apparent connection to a lightning bolt;
- Unusual surges of radiation at 511 keV when there were no thunderstorms;
- Beams of antimatter (positrons) produced above thunderstorms on Earth;
- A gamma-ray flash coming down from the overhead thundercloud;
- Some discharges make x-rays and others do not;
- Explosive production of energetic particles observed from space;
- Thunderstorms make electron and positron beams;
- Thunderstorms produce TGFs;
- A bright TGF was seen by spacecraft in the middle of Sahara Desert on a nice day;
- The spectra of TGFs at very high energies (~40 - 100 MeV).

Geocorona is the luminous part of the outermost region of the Earth's atmosphere. It extends to at least 640,000 km from the Earth. X-rays from Earth's Geocorona in the range of energies 0.08 - 10 keV were first detected in 1999. The main mechanism explaining the geocoronal x-rays is that they are caused by collisions between neutral atoms in the Geocorona with carbon, oxygen and nitrogen ions in the solar wind [32] [33] [34]. This process is called "charge exchange", since an electron is exchanged between neutral atoms in Geocorona and ions in the solar wind.

According to WUM, the characteristics of Geocorona are similar to the characteristics of the Solar Corona [1]:

- The Geocorona composed of Dark Matter Fermions DMF1 with mass 1.3 TeV has the size that is much larger than the size of the Earth;

- At the distance of 640,000 km from the Earth, atoms and molecules are so far apart that the outermost region of the Earth's atmosphere no longer behaves like a gas;
- X-rays and gamma-rays are the consequence of DMF1 annihilation;
- The Geocorona made up of DMPs resembles a honeycomb filled with plasma including the ionosphere from about 60 km to 1000 km altitude;
- The calculated density of the Geocorona near the surface of the Earth is $2.5\times10^{-7}\ \mathrm{kg/m^3}$.

As the result of DMPs annihilation, x-rays and gamma-rays are going not only up and out of the Earth, but also down to the Earth's surface. In case they were produced at altitudes of above at least 30 km, they can reach the orbiting detectors [19]. In case the source altitudes of the gamma rays is below about 20 km [23] [27] [28] [29] (within the altitude range of thunderstorms), they can reach the surface of the Earth (see **Figure 1**).

In our view, TGFs are, in fact, well-known GRBs [36]. The spectra of TGFs at very high energies can be explained by DMF1 annihilation. Lightning initiation problem can be solved by x-rays and gamma-rays, which slam into the thunderclouds and carve a conductive path through a thunderstorm. From this point of view, it is easy to explain all experimental results summarized above.

5. Multiworld

According to A. G. Oreshko, "*P. L. Kapitsa supposed that a ball lightning is a window in another world*" [37]. We analyzed possibility of the existence of other worlds: Micro-World, Small-World, and Large-World based on the proposed Weak, Super-Weak and Extremely-Weak interaction respectively [38]. It was suggested that BL is an object of the Small-World. Below we discuss main characteristics of the proposed new Worlds in the Multiworld.

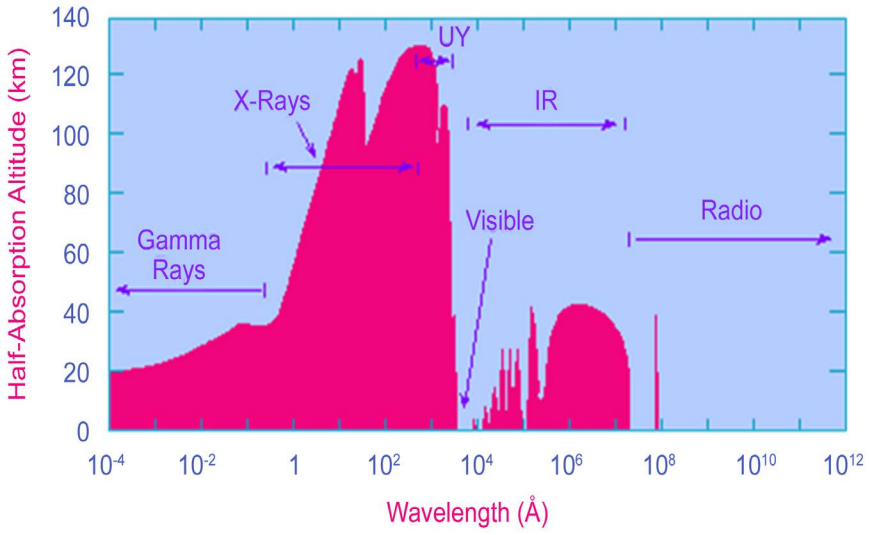

Figure 1. Atmospheric Windows. Adapted from "Atmospheric Windows" by Eric G. Blackman [35].

Macro-World: According to WUM, strength of gravity is characterized by gravitational parameter G_g:

$$G_g = G_0 \times Q^{-1} \propto \tau^{-1}$$

where $G_0 = \frac{a^2 c^4}{8\pi hc}$ is an extrapolated value of G_g at the Beginning of the World ($Q = 1$), c is the electrodynamic constant, h is Planck constant, a is a basic unit of length: $a = \alpha\lambda_e$, λ_e is the Compton wavelength of an electron and α is Sommerfeld's constant that is, in fact, the ratio of electron mass m_e to the basic unit of mass m_0: $\alpha = m_e/m_0$ and m_0 equals to: $m_0 = h/ac$ [1]. Dimensionless time-varying quantity Q is a measure of the Age of the World: $Q = \tau/t_0$ where τ is a cosmological time and a basic unit of time t_0 equals to:

$$t_0 = a/c = 5.9059674 \times 10^{-23} \text{ s}$$

In the present epoch, Q equals to [39]:

$$Q = 0.759972 \times 10^{40}$$

The range of gravity equals to the size of the World R:

$$R = aQ = 1.34558 \times 10^{26} \text{ m}$$

The total mass of the Macro-World M_{tot} is:

$$M_{tot} = 6\pi^2 m_0 \times Q^2 = 4.26943 \times 10^{53} \text{ kg}$$

WUM foresees three additional types of interactions: Weak, Super-Weak, and Extremely-Weak, characterized by the following parameters respectively:

$$G_W = G_O \times Q^{-1/4} \propto \tau^{-1/4}$$

$$G_{SW} = G_O \times Q^{-1/2} \propto \tau^{-1/2}$$

$$G_{EW} = G_O \times Q^{-3/4} \propto \tau^{-3/4}$$

In our view, each type of interaction provides integrity of the corresponding world (see Table 1).

Micro-World is characterized by the parameter G_W, which is about 30 orders of magnitude greater than G_g. The range of the weak interaction R_W in the present epoch equals to:

Table 1. Parameters of Multiworld (ρ_0 is a basic unit of density: $\rho_0 = h/ca^4$).

Type of world	Type of Interaction	Relative Interaction Parameter G/G_0	Relative Range of Interaction r/a	Relative Total Mass $M_{max}/4\pi m_0$	Relative Density of World $\rho/3\rho_0$
Macro-World	Gravity	Q^{-1}	Q	$1.5\pi \times Q^2$	Q^{-1}
Large-World	Extremely-Weak	$Q^{-3/4}$	$Q^{3/4}$	$Q^{3/2}$	$Q^{-3/4}$
Small-World	Super-Weak	$Q^{-1/2}$	$Q^{1/2}$	Q	$Q^{-1/2}$
Micro-World	Weak	$Q^{-1/4}$	$Q^{1/4}$	$Q^{1/2}$	$Q^{-1/4}$

$$R_W = a \times Q^{1/4} = 1.65314 \times 10^{-4} \text{ m}$$

that is much greater than the range of the weak nuclear force (around $\sim 10^{-16}$ - 10^{-17} m).

With Nikola Tesla's principle at heart—*There is no energy in matter other than that received from the environment*—we apply to the Micro-World the following equation for a maximum total mass M_W :

$$M_W = 4\pi\sigma_0 R_W^2 / c^2 = 4\pi m_0 \times Q^{1/2} = 1.36752 \times 10^{-7} \text{ kg}$$

where σ_0 is a basic unit of surface energy density: $\sigma_0 = hc/a^3$. The average density of the Micro-World ρ_W is:

$$\rho_W = 3\rho_0 \times Q^{-1/4} = 7.22621 \times 10^3 \text{ kg/m}^3$$

In our opinion, Micro-World objects with mass about Planck mass are the building blocks of all Macroobjects.

Large-World is characterized by the parameter G_{EW} , which is about 10 orders of magnitude greater than G_g . The range of the extremely-weak interaction R_{EW} in the present epoch equals to:

$$R_{EW} = a \times Q^{3/4} = 1.44115 \times 10^{16} \text{ m}$$

In our view, Extrasolar Systems (ESSs) are Large-World objects with spherical boundary between ESS and Intergalactic Medium. This boundary has a surface energy density σ_0 . Maximum total mass of ESS equals to:

$$M_{EW} = 4\pi\sigma_0 R_{EW}^2 / c^2 = 4\pi m_0 \times Q^{3/2} = 1.03928 \times 10^{33} \text{ kg}$$

and average density ρ_{EW} equals to:

$$\rho_{EW} = 3\rho_0 \times Q^{-3/4} = 8.28918 \times 10^{-17} \text{ kg/m}^3$$

which is about 10 orders of magnitude greater than the critical density [1]. In WUM, ESSs have Cores made up of DMPs surrounded by shells composed of DM and baryonic matter. Extremely-weak interaction between DM Cores and all particles around them provide integrity of ESSs.

Small-World is characterized by the parameter G_{SW} , which is about 20 orders of magnitude greater than G_g . The range of the super-weak interaction R_{SW} in the present epoch equals to:

$$R_{SW} = a \times Q^{1/2} = 1.54351 \times 10^6 \text{ m}$$

A maximum total mass of Small-World M_{SW} is:

$$M_{SW} = 4\pi m_0 \times Q = 1.19215 \times 10^{13} \text{ kg}$$

and average density ρ_{SW} equals to:

$$\rho_{SW} = 3\rho_0 \times Q^{-1/2} = 7.73947 \times 10^{-7} \text{ kg/m}^3$$

which is about 20 orders of magnitude greater than critical density [1]. **Table 2** describes parameters of Small-World objects made up of different fermions taking part in the super-weak interaction.

In WUM, BLs have Cores made up of DMPs surrounded by shells composed

Table 2. Parameters of Small-World objects made up of different fermions DMF1, DMF2, and electron-positron plasma.

Fermion	Fermion mass, m_f, MeV/c^2	Macroobject mass, M_{max}, kg	Macroobject radius, R_{min}, m	Macroobject density, ρ_{max}, kg/m^3
Interacting DMF1	1315×10^3	2.3	9.2×10^{-7}	7.2×10^{17}
Interacting DMF2	9596	2.3	9.2×10^{-7}	7.2×10^{17}
Electron-positron plasma	0.511	8×10^6	3.1	6.4×10^4

of electron-positron plasma. Super-weak interaction between DM Cores and all particles around them provide integrity of BLs (see next Section).

6. Ball Lightning Formation

The clue of our model comes from the observed ability of BLs to penetrate solid materials. It means that the Core of BL should be composed of DMPs. In WUM, they are DMF1 and DMF2. Fermion small-stars made up of DMF1 or DMF2 can form Cores of BLs in the Small-World characterized by super-weak interaction.

Following Tesla vacuum hypothesis [4] [5], we suppose that when sudden and very powerful TGF passes through the air and strike the surface of the Earth, "*the tremendous expansion of some portions of the air and subsequent rapid cooling and condensation gives rise to the creation of partial vacua in the places of greatest development of heat. These vacuous spaces, owing to the properties of the gas, are most likely to assume the shape of hollow spheres when, upon cooling, the air from all around rushes in to fill the cavity created by the explosive dilatation and subsequent contraction*".

In our Model, the places of greatest development of heat are the spots on the Earth's surface struck by TGFs. As the result, the ablation of the soil takes place and vaporized chemical elements of soil and the oxygen and nitrogen from the air can be absorbed by BLs and observed experimentally [16].

Very powerful gamma quants with energy at least 1.02 MeV in the vicinity of atomic nuclei of the ground can produce electron-positron pairs with high concentration. This collisionless unmagnetized electron-positron plasma, whose properties are very well studied, composes a shell around DM core of BL made up of DMF1 and provides their affinity for metal objects such as wires [16].

The most important part of the BL formation is a DM core. The calculated density of the Geocorona composed of DMF1 ρ_{DMF1} near the surface of the Earth is [1]:

$$\rho_{\mathrm{DMF1}} \cong 2.5 \times 10^{-7} \ \mathrm{kg/m^3}$$

According to WUM, in the Small-World DMF1 and a microobject will exert super-weak interaction on one another when the minimum product of their masses m_{DMF1} and M_{micro} equals to [39]:

$$m_{\mathrm{DMF1}} \times M_{micro} = 2m_0^2 \times Q^{1/2} = 2.71692 \times 10^{-36} \ \mathrm{kg^2}$$

Dark Matter particle DMF1 has a mass m_{DMF1}:

$$m_{\mathrm{DMF1}} = 2.34419 \times 10^{-24} \text{ kg}$$

Then the minimum mass of microobject should be

$$M_{micro} \approx 1.16 \times 10^{-12} \text{ kg}$$

Let's calculate a radius of a sphere in Geocorona r_{micro} having minimum mass M_{micro}: $r_{micro} \cong 10^{-2}$ m. When powerful TGF strikes the surface of the Earth, the explosive dilatation of this portion of Geocorona with radius r_{micro} gives rise to the creation of hollow sphere with partial vacua and all DMPs outside of the sphere. The subsequent rapid contraction induces DMPs rush in to fill the cavity. As the result, at the center of the sphere arises microobject with minimum mass M_{micro} and density high enough for the beginning of the DMPs annihilation.

The estimations, based on the average density of the moon Mimas about ~10^3 kg/m^3 with the Core made up of annihilating DMF1 [1], show that the size of the microobject should be about ~10^{-5} m. The described microobject attracts new DMPs from Geocorona due to super-weak interaction and grows up to the next value of a mass of the macroobject M_{macro}, which can be calculated in accordance with the following equation:

$$m_e \times M_{macro} = 2m_0^2 \times Q^{1/2}$$

where m_e is a mass of electron: $m_e \approx 9.11 \times 10^{-31}$ kg. Mass of the macroobject equals to:

$$M_{macro} \cong 3 \times 10^{-6} \text{ kg}$$

This macroobject will start attracting electron-positron pairs produced by TGF. Considering the density of the atmosphere $\rho_{atm} \cong 1.25 \text{ kg/m}^3$ we can calculate the minimum radius of the BL $r_{\min}$:

$$r_{\min} \cong 0.83 \times 10^{-2} \text{ m}$$

that is in good agreement with experimentally observed value of BL minimum size about ~1 cm [3]. We take the density of the atmosphere ρ_{atm} for the average BL density to explain movement of BL in air.

According to WUM, mass of BL's core can grow up to 2.3 kg and the radius of plasma shell can be a few meters (see **Table 2**). Mass of the small BLs is mostly in the DM cores. Then they can easily penetrate through walls, glass and metal, generally without leaving a hole. Practically all mass of the EBLs is in the plasma. EBL with diameter 5 m observed in [16] had the mass of about 83 kg.

In our opinion, Nuclear Fireball is a huge EBL.

As the conclusion:

- BL has the core made up of DMF1 surrounded by the electron-positron plasma contaminated by chemical elements of soil and air as the result of TGF strike of the ground;
- The core of BL irradiates quants with different energies and attracts new DMPs from Geocorona due to super-weak interaction. It explains the observed result that the brightness of BL remains fairly constant during its life-

time;

- DMPs supply not only additional mass, but also additional angular momentum [1]. It explains the fact that many of BLs are described as having rotational motion;
- World-Universe Model can serve as a basis for High-Energy Atmospheric Physics.

It is important to emphasize that the initial energy required for a BL/EBL creation is insufficient for its sustenance of up to 1200 seconds. Additional energy, therefore, must be consumed by a BL/EBL once it had been formed. Once we master the creation of BLs and EBLs in a controlled environment, we can concentrate our efforts on harvesting that energy.

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Conflicts of Interest

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

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