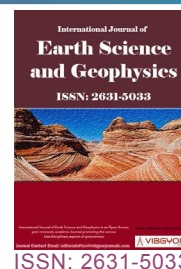


# Circulating Light in a Form of Ball Lightning in Earth's Atmosphere



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## Abstract

Ball lightning is a mysterious natural phenomenon, the generally accepted explanation for which does not exist to date. At the same time, about 20 years ago, we proposed an optical model of ball lightning, according to which, contrary to popular belief, ball lightning is in no way connected with either electricity or plasma. Ball lightning contains only two components - conventional air and white light. Ball lightning is a thin spherical layer of highly compressed air in which ordinary white light circulates in all possible directions. It is shown that the necessary conditions for the stability of such a formation can be satisfied and physical parameters required for the stability are calculated. We have shown in numerous articles that the behavior of such a formation in the Earth's atmosphere completely coincides with the intriguing behavior of natural ball lightning. We regard this circumstance as experimental confirmation of the correctness of our theory. However, the theory has not gained general acceptance. This is not surprising, since it is difficult for people to accept that light can circulate to a limited volume without outside assistance. Later we discovered that there is a whole world of known anomalous objects in which circulating light plays a decisive role in their anomalies. The study of this phenomenon gives grounds to state that in the earth's atmosphere there is such a phenomenon as circulating light. The characteristic features of this phenomenon are presented.

## Keywords

Circulating light, Electrostriction pressure, Ball lightning, Centrifugal pressure, Optical space soliton, Analysis of stability

## Introduction

The phenomenon called ball lightning is a natural phenomenon that is observed usually in the Earth's atmosphere in thunderstorm at a discharge of ordinary linear lightning. Sometimes the discharge is accompanied by an appearance of a luminous ball that is called fireball or ball lightning. Unlike the linear lightning, a duration of which is several milliseconds, a life time of the ball lightning can

achieve several minutes. This phenomenon has been known for several centuries.

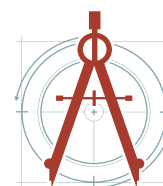
Currently, more than 500 different theories and hypotheses about the nature of this phenomenon are known and several thousand articles have been published. But the mysterious and intriguing behavior of ball lightning, which is described in many books and databases, remains unexplained. Indeed, ball lightning can penetrate rooms through

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window panes, can find gaps and penetrate rooms through them, changing its spherical shape if necessary, can catch up with flying airliners and penetrate into cabins, can move against the wind, it disappears unexpectedly suddenly instantly, traceless.

As the author of one of the scientific books about ball lightning said out of desperation: "All theories are united by one thing, they do not work". It is this information that allows us to assert that the intriguing, mysterious, paradoxical behavior of ball lightning in the Earth's atmosphere cannot be explained by any theory that considers some material objects.

Faraday supposed that ball lightning is not connected with electricity. Lord Kelvin believed that an object that has a set of properties inherent in ball lightning cannot exist, and reports of observations are explained by illusions. Pyotr Kapitsa, a Russian scientist, Nobel Prize winner, studying the phenomenon of ball lightning, was forced to admit at the end of his life that this plasma nut was too strong for his teeth. At the same time, he suggested that ball lightning is a phenomenon from another world unknown to him. Indeed, he was partly right. He was wrong that ball lightning was related to plasma, but he was right that ball lightning belongs to another world unknown to him.

Observational properties of Ball Lightning are given in books such authors as Singer [1], Stakhanov [2], Barry [3], Steinhoff [4], where above thousand the most revealing events are described in detail. "Ball lightning: an unsolved problem of Atmospheric Physics" - is the name of the monograph, published in 1999 [4]. We can specify this statement and say that the Ball Lightning is a shame of modern physics. Physicists cannot imagine an object obeying accepted laws of physics, the properties of which would coincide with the observed properties of Ball Lightning. Moreover, for 20 years they cannot figure out that there is a whole unique world of circulating light, in which natural Ball Lightning is only one of many other natural objects with anomalous properties.

Among these seemingly incompatible properties in one object, the following abnormal properties significantly simplify the solution of the problem.

First, we take into account the anomalous property of Ball Lightning to move in a direction that

does not coincide with the direction of the wind. A separate section entitled "Flies against wind" in the Sagan book that is based on declassified Ball Lightning information of the USA Oak Ridge National laboratory [5] is devoted to a description of this property.

Second, we take into account the anomalous property of Ball Lightning to penetrate in rooms through window panes. This wonderful property is confirmed by 43 similar cases described in [6].

Third, Ball Lightning can catch up and accompany a flying airliner. An entire chapter entitled "Airplane Crashes" is devoted to a description of this phenomenon [5]. In this case, Ball Lightning is not blown away by the wind, whose speed exceeds the wind speed in the strongest hurricane.

We can conclude from these properties that Ball Lightning does not contain material objects (electrons, ions, atoms, molecules, clusters, etc.), since material things cannot penetrate through glass. Besides, since the time of Newton it has been known that the motion of any object is determined by external forces. This means that any object consisting of material particles will be immediately blown away by the wind, regardless of the specifics of internal forces and internal processes by which ball lightning researchers try to explain the existence of Ball Lightning's. Only light is not blown away by the wind. The light moves in accordance with its own laws.

Bearing in mind these circumstances, we can conclude that none of the known hypotheses satisfies these requirements, since it is difficult to imagine a hypothesis in which it is stated that ball lightning consists of nothing.

Such unusual, mysterious properties of Ball Lightning have a great advantage. They allow one to easily reject various theories and hypotheses about the nature of Ball Lightning because the objects proposed as ball lightning do not have the same abnormal properties that natural Ball Lightning has. On the other hand, the same set of anomalous properties allows us to assert with great confidence that an object is Ball Lightning if it fully possesses the same anomalous properties as natural Ball Lightning.

What then can an object consist of? Ball Lightning radiates light. So light is a component of the object. But how can an object radiate light if

hot atoms are not included in its composition? This can only happen if the pre-produced and already existing light is somehow enclosed in the volume of ball lightning. In principle, this is possible if light circulates along closed paths. This is not possible in a vacuum because light travels in a straight line. In the Earth's atmosphere, which can be considered as a nonlinear optical medium, this is possible in principle.

Keeping these considerations in mind, we invented in 2003 a perfectly new object and have published the article where we have shown that our object has the same set of anomalous properties as natural Ball Lightning [7]. Properties and physical parameters of this object have been presented. Since 2003 we have published about eight dozen papers in leading international journals on physics and optics where we tried to convince the scientific community that Ball Lightning is circulating light and to show that all anomalous properties of natural Ball Lightnings are identical to that of our ball light [7-18]. Note that the number of publications on our theory is an order of magnitude larger than on any other known theory or hypothesis. Usually, such theories are limited only to the suggestion of some luminous object, which may have one or several properties of natural Ball Lightning. Further studies of this object show that the properties of this object are far from the anomalous properties of natural Ball Lightning.

### Physical Nature of Ball Lightning

Ball lightning is an entirely unusual physical object. Previously, no one suspected its existence. Therefore, it could not be studied either theoretically or experimentally. Of course, this object has no name.

This object is a singularity in the Earth's atmosphere that usually arises at a strike a conventional linear lightning. The strike of the conventional lightning is accompanied by the shock wave. The intense white light radiated by the edge of the shock wave occurs in a trap produced by the shock wave where hot air atoms radiate white light. In short, this object is the conventional white light circulating in a thin spherical film of conventional compressed air. This single sentence expresses the essence of ball lightning.

The essence of our optical model of ball lightning is most comfortable to explain when comparing

this object with a well-known thing in the form of a soap bubble. Unlike a soap bubble, the shell of this object consists of a thin spherical layer of strongly compressed air where conventional intense white light is circulating in all possible directions. The light compresses the air to minimize the total energy of the light and compressed air. The reflective index of the compressed air is greater than that of the surrounding air. In this case, the shell is a spherical 2D lightguide that prevents radiation of light in free space. Thus, our object is a symbiosis of two elements. These are the air and light. Compressed air helps the existence of circulating light, and circulating light ensures the existence of compressed air.

This short explanation can be clarified a bit. The air pressures inside and outside the spherical layer of compressed air are the same and equal to atmospheric pressure. Unlike a soap bubble, in which its spherical shape is provided by the excess air pressure inside the soap film, the spherical shape of our object is provided by the centrifugal force produced on the layer by the light circulating in it. The glow of ball lightning is explained by the fact that the circulating light is gradually scattered due to molecular light scattering. Similarly, sunlight is scattered in the earth's atmosphere, which explains the blue color of the sky. In these two paragraphs, we have fully described the physical nature of ball lightning.

### Grounds Confirming the Correctness of the Optical Theory of Ball Lightning

There is a legitimate question. What grounds are there for believing that the theory under consideration is the only true one, in contrast to the other 500 theories, which, without consideration, are ranked as incorrect? How can be proved that such an imaginary object in a form of ball light exists in nature and is Ball Lightning? We have not met a person who would not express surprise and doubt. The light travels in a straight line. Why should it spin? If the compressed air is not confined by anything, it will expand in all directions. Why can such an object be stable? Our explanation is based on the theory of the optical model of ball lightning presented in eighty scientific papers in leading international scientific peer-reviewed journals in physics and optics.

Any skeptic would require experimental

confirmation of this model. Any model only approximately describes the real phenomenon and requires experimental confirmation. Fortunately, nature presents numerous experimental samples in the form of natural ball lightning's and a complete set of information about their properties in the form of numerous eyewitness accounts. From this information, it follows that the experimental sample has such a set of anomalous properties (inexplicable on the basis of modern knowledge) that are absent in numerous known models of ball lightning. The exception is our model, which, as shown below, has the same set of so-called anomalies. It is shown that the properties of ball lightning are not anomalous, but are in full accordance with the existing laws of optics and physics. Thus, circulating light is not a game of imagination, but an objective reality.

We believe that the criterion for the correctness of the theory is the coincidence of the behavior of the object under consideration in the Earth's atmosphere with the behavior of natural ball lightning, the behavior of which has numerous eyewitness accounts, photographs, and videos. The correctness of the optical nature of Ball Lightning does not follow from the theoretical reasoning but is based on the striking similarity of the behavior of the ball light and Ball Lightning in all situations in which the inexplicable, mysterious, and intriguing behavior of Ball Lightning is noted. A similarity of behaviors of ball lights and Ball Lightning is shown for two dozen of the most mysterious situations [8,12-18].

The greatest scientist Faraday after whom the unit of electrical capacity is named said: "Nothing is too wonderful to be true if it is consistent with the laws of nature." The famous American writer Mark Twain also respected reality. He believed that "fiction is obliged to stick to possibilities. Truth isn't".

The proof was carried out in the following directions.

First, knowing the physical nature of a ball light, we can show that its behavior in the Earth's atmosphere entirely coincides with the mysterious and intriguing behavior of Ball Lightning.

Secondly, we have shown that Ball Lightning is not the only object in a completely new world where circulating light plays a decisive role. We present an analysis of other abnormal luminous

objects from the world of circulating light and show that it is the circulating light that is responsible for their anomalies. Accounting for the presence of circulating light in these objects makes it possible to explain these anomalies.

## Physical Laws Responsible for Abnormal Properties of Ball Lightning

This is due to the fact that light circulates in a limited volume of a thin spherical layer, in contrast to light propagating in a straight line, the volume of which increases in time with the speed of light. As a result, the energy density of circulating light is billions of times greater than the energy density of light propagating in a straight line. It is known that so-called optically induced forces act on the light propagating in an inhomogeneous optical medium. Their magnitude is proportional to the energy density of the light. These forces are negligible at ordinary light intensities. However, if the energy density of the light increases billions of times, these forces increase to the same extent and become comparable in magnitude, and sometimes even surpass other known types of forces. It is shown that it is the optical-induced forces that are responsible for all the anomalies in the behavior of natural ball lightning in the Earth's atmosphere.

The behavior of well-known objects obeys the laws of mechanics. The behavior of an object consisting mainly of light obeys the same laws of mechanics. The only difference is that an additional optically induced force begins to act on objects with circulating light, which is comparable in magnitude, and sometimes exceeds other types of forces. This force also acts on ordinary objects, but its magnitude is so small that significant efforts are required to measure it, even with the current state of the art.

Since the time of Snell in the 18th century, it has been known that light propagating in an inhomogeneous optical medium is deflected in the direction where the reflective index increases. Thus *circulating light is moving in the direction of increasing the air reflective index*. Using more understandable physical parameters, we can say that the *circulating light moves in the direction of increasing the Earth's air density*. If we take into account that the air pressure is the same in the area where ball lightning is usually observed, then the lower the temperature, the higher the air



density. Thus, the behavior of ball lightning obeys the simplest rule. *Ball lightning tends to move in the direction of decreasing the air temperature.* However, in some cases, when moving over long distances, ball lightning moves in the direction of increasing air density. This situation occurs when ball lightning catches up with an aircraft that disturbs the uniform distribution of air density in such a way that the maximum air density is at the leading edge of the fuselage and wings of the aircraft.

Typically, the temperature distribution of the atmosphere air is influenced by various obstacles in the form of buildings, trees, etc. Besides, the circulating light itself affects the distribution of air temperature around it. When approaching such obstacles, the effect of self-action arises. Ball lightning heats obstacles with its radiation. In turn, the obstacles heat the surrounding air around them. As a result, the ball lightning bypasses obstacles, penetrates cracks, etc. In other words, the circulating light forces the ball lightning to behave entirely differently than other ordinary objects.

### Circulating Light in Other Anomalous Glowing Objects

In the past two centuries, researchers have been working on producing Ball Lightning in a laboratory. They obtained luminous objects with anomalous properties. However, neither in size nor in life time, they corresponded to a natural Ball Lightning. Analyzing the anomalies of these objects, we came to the conclusion that the anomalies can be explained by assuming that the objects contain circulating light. Then one can consider a natural Ball Lightning not as a unique phenomenon, but as one of the representatives of a wider class of phenomena in which circulating light participates.

Unlike a natural Ball Lightning, which is a rare natural phenomenon and cannot be systematically investigated, the physical properties of anomalous objects can be analyzed using existing test devices. Over the past two centuries, a great deal of experimental data has been accumulated on the parameters of anomalous objects. Just by studying these data and bearing in mind the participation of circulating light in an appearance of anomalies, we can explain the nature of these anomalies and obtain a lot of valuable information from the world

of circulating light at the time when sceptics shake their heads and express doubts about the optical nature of Ball Lightning.

For example, an analysis of the emission spectra of abnormal phenomena when a liquid nitrogen vapor is illuminated by a powerful flash lamp allowed us to discover a phenomenon of self-organization of intense light in gasses. Also, we discovered a new mechanism for increasing the reflective index in a gas mixture by studying the published spectrum of luminous anomalous objects. Comparing the values of the reflective index of the elements represented in the spectrum of anomalous objects, we found that there are elements, the reflective index of which is greater than that of the air. Thus, nature suggested another way to increase the reflective index in the shell of ball light. The reflective index may increase not only due to an increase in the air density because of an increase in the air pressure but also due to the drawing into the shell of the components of the gas mixture with the maximal reflective indices.

Another example: It was known from experiments that an erosive gas discharge has a beneficial effect on the production of luminous objects with anomalous properties. Taking into account the mentioned above mechanism, we enabled to explain this beneficial effect.

One more example: More recently, a video appeared on YouTube in which a luminous ball jumps on a table for 8 seconds, making over a dozen bounces. Only taking into account the circulating light made it possible to explain this phenomenon and show that circulating light can exist not only in compressed air but also in a liquid. Besides, the circulating light can arise and exist due to exothermic chemical reactions.

For almost 100 years, a phenomenon has been known when, under the action of ultrasound, a bubble begins to glow in the water. Moreover, its spectrum corresponds to a temperature of a hundred of thousand degrees. This phenomenon has received its own name sonoluminescence. Attempts are known to use this phenomenon to carry out thermonuclear reactions in a test tube with water. We have shown that the glow of the bubble is associated with circulating light, the spectrum of which shifts to the short-wavelength region when the light is compressed with decreasing the bubble

size. Therefore, there is no temperature of hundred thousand degrees in the bubble, and attempts to obtain a thermonuclear reaction are in vain.

Thus, the study of the published properties of luminous anomalous objects from the world of circulating light allowed us not only to explain the anomalies of these objects, but also to discover new phenomena that are responsible for these anomalies.

### Stability and Physical Parameters of Ball Light

Quite a lot of effort has been spent on substantiating the stability of circulating light. Indeed, it follows from simple common sense that the gas compressed in a spherical shell tends to expand. The circulating light tends to propagate linearly and therefore also tends to increase the diameter of the spherical shell. Where are the forces that oppose these trends? For simple reasons, there is no answer to this question.

From more scientific considerations, it follows that the stability of some stationary state of an isolated system takes place when the total energy of the system is minimal.

Estimating this energy, one can make sure that the energy of compressed air is always a decreasing function of its volume or of the diameter of the spherical shell. The energy of the circulating light also decreases with increasing diameter of the spherical shell, since light tends to increase the shell diameter. The circulating light produces a positive mechanical work on the shell expansion. This leads to a corresponding decrease in its energy. As a result, the energy of the circulating light also decreases with increasing of the shell diameter. A sum of two decreasing functions cannot have a minimum. Consequently, the necessary conditions of stability are not met for circulating light and, consequently, it cannot exist.

However, the behavior of a hypothetical circulating light in the earth's atmosphere completely coincides with the behavior of a real existing object in the form of natural ball lightning. It is required to find an error in the above reasoning. An error has been found. It must be taken into account that light circulates in the optical medium and its energy changes when the refractive index of the optical medium changes. As the shell expands, the refractive index of the compressed air

decreases, which leads to an increase in the energy of the circulating light. Of course, with compressed air, the refractive index of which differs from unity in the third decimal place, the change in the refractive index is so small that it cannot affect the picture described above. But in the case when the refractive index is comparable to the refractive index of water or glass, the situation will change. In this case, a change in the volume of the shell leads to a significant change in the refractive index, which leads to a significant increase in the energy of light. As a result, the dependence of the energy of light on the diameter of the shell becomes an increasing function, which opens the way to the appearance of a minimum of the total energy of light and compressed air.

The calculations performed show that the conditions of stability begin to be fulfilled if the degree of air compression is about 1000. In this case, the density of compressed air is comparable to the density of water. In this case, the pressure of compressed air is increased as compared with that at normal conditions by more than 20,000 times. As a result, the pressure of compressed air exceeds 2 GPa [19].

These results agree with the results obtained from other considerations based on the reasons for the anomalously long lifetime of circulating light. It is known that the lifetime of ordinary white sunlight propagating in the earth's atmosphere is tens of milliseconds. The lifetime of natural ball lightning and, consequently, of circulating light is tens of seconds, that is, 3 orders of magnitude longer.

The lifetime is determined by the molecular scattering of light by inhomogeneities in the density of air, which arise due to the chaotic motion of its molecules. With an increase in air pressure, its compressibility decreases and the inhomogeneity of air density decreases. It is shown that the lifetime of light in compressed air increases by 3 orders of magnitude at an air pressure of about several gigapascals [7], which is consistent with the pressure obtained from the stability condition [19].

### Future of the Circulating Light

Two decades have passed since convincing evidence was presented that the behavior of the circulating light and natural Ball Lightning is the same, and therefore the circulating light exists in nature. It would seem that the discovery of a new

natural phenomenon should have aroused an interest in it and in the study of the presence of the circulating light in other natural phenomena. However, this did not happen.

Analyzing the new knowledge gained, we came to the conclusion that this knowledge can be used not only in future but also in past for an alternative explanation of past anomalous phenomena, in particular, for explaining the causes of the Chernobyl accident. Based on the combination of numerous, seemingly insignificant circumstances, it was shown that the real cause of the accident could be a "ball lightning" that occurred a minute before the explosion at the beginning of the planned safe electrical tests [20].

## Conclusion

Believing a priori, that bubbles of light are an objective reality, we have shown that in accordance with well-known laws of physics behavior of bubbles of light in earth's atmosphere is completely identical to mysterious and paradoxical behavior of natural ball lightning. Too many puzzles related to ball lightning can be explained by the assumption that ball lightning is a circulating light. A natural ball lightning has properties which combination is absent in any known object. None of above 500 existing now theories of ball lightning can explain combination of properties inherent to ball lightning. Perfectly new unknown up to now object which has all properties of ball lightning is required. We have shown that all properties of our bubble and a natural ball lightning are the same. It is unlikely that this is a mere coincidence. Ought to underline that the existence of bubbles of light in nature is based not on theoretical rational but on wonderful coincidence of behaviors of bubbles of light and ball lightning in air atmosphere as well as on their common physical properties.

## Declaration of Competing Interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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