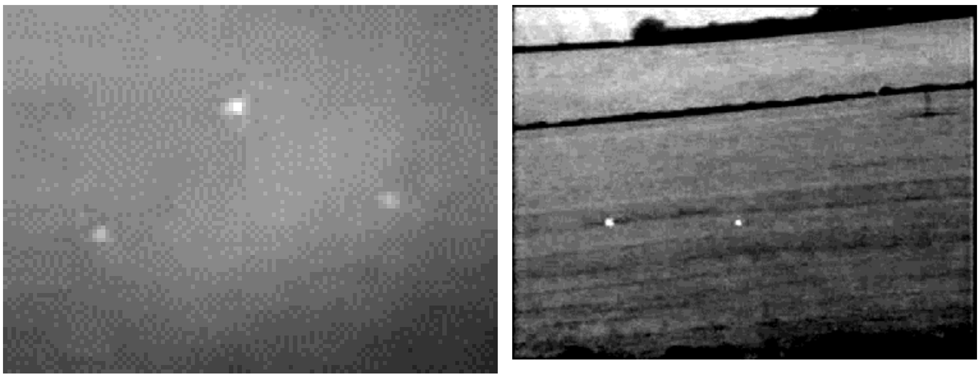
Proc. of 5th Internationsl conference “Atmosphere, Ionosphere, Safety” (AIS-2016). Kaliningrad, Russia, 2016. P. 274-278.

Observation and Analysis of Ball Lightning Group Flights

Anatoly I. Nikitin, Alexander M. Velichko, Tamara F. Nikitina,
Alexander I. Stepanov, and Ilya G. Stepanov
Talrose Institute for Energy Problems of Chemical Physics, Russian Academy of Sciences, Moscow, 117829, Russia

There are many evidences in literature and Internet about observation in atmosphere of spherical luminous objects, which form combined structures – dumbbells, triangles, squares and so on [1-5].



(a) (b)

FIGURE 1. Photos of groups of ball lightning.

Fig. 1a is a photo of three light sources, flowing in the sky as a triangle [6]. Fig 1b is a frame from the film, where a pair of ball lightning (BL) was flowing over a corn field [7]. These balls move as if they are connected by an invisible thread, a ratio of a distance between the balls to their diameter is about 15. According to the electrodynamical model of ball lightning, it has a non-compensated positive electric charge [8-10]. This charge slowly leaks to atmosphere. A loss of the charge, which supports a stability of BL, in the end results its dead. Let us explain the existence of BL groups, basing on the sole assumption: of the presence in it of electric charge. The charge of the same sign pushes BLs away by the Coulomb force. However the forces preventing pushing away of BL may act in a group of these objects. These forces are a ”gradient” force, arising due to polarization of BL substance, and forces, connected with gradual leaking of BL charge to atmosphere. Our purpose is to estimate the contribution of these forces into interaction of BL groups and to try to find conditions of existence of steady configurations from the charged objects.

For modeling of interaction between BLs we performed experiments for measurement of force, pushing away two the same charged balls for table tennis. Balls in radius a = 2 cm and mass m = 2.72 g were suspended on a thin copper wire of length L = 57 cm, and a positive potential U from 0 to 30 kV was supplied to them. Measuring a ball deviation angle from a starting position, we found a force, acting on it from the other ball. A charge of the ball is $Q = 4\ \pi\varepsilon_0 aU$, and a Coulomb force is:

$$F_c = 4\ \pi\ \varepsilon_0 a^2 U^2/R^2, \tag{1}$$

where R is a distance between the balls centres.

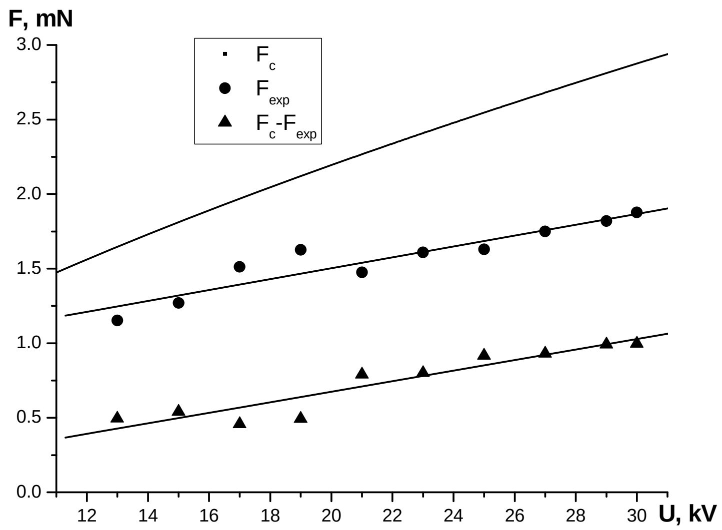


FIGURE 2. Dependence on voltage of a force, pushing away two plastic balls of diameter 4 cm.

Fig. 2 shows a dependence F_c from U, constructed under the formula (1) (the top curve). A middle curve is an experimentally found dependence of force of pushing apart of balls F_{exp} on potential U. One can see that this force is approximately in 1.5 times less than Coulomb force F_c. The bottom curve is a dependence of this additional force $F_{gr} = (F_c - F_{exp})$, decreasing action of the Coulomb force, on potential U. Force F_{gr} can appear because of polarization of substance of a ball in the non-uniform electric field E, created by other ball.

$$F_{gr} = D\cdot\text{grad}\ E = 2DQ/4\pi\varepsilon_0 R^3. \tag{2}$$

Here D is a dipole moment of the ball, ε_0 is an electric constant, $R^3 = 4\pi\varepsilon_0 a^2U^2\cdot 2L/mg$ is a cube of a distance between centres of balls, and g is an acceleration of free falling. Substituting in (2) expressions for R^3 and Q, we have:

$$F_{gr} = D\cdot mg/4\pi\varepsilon_0 aUL. \qquad (3)$$

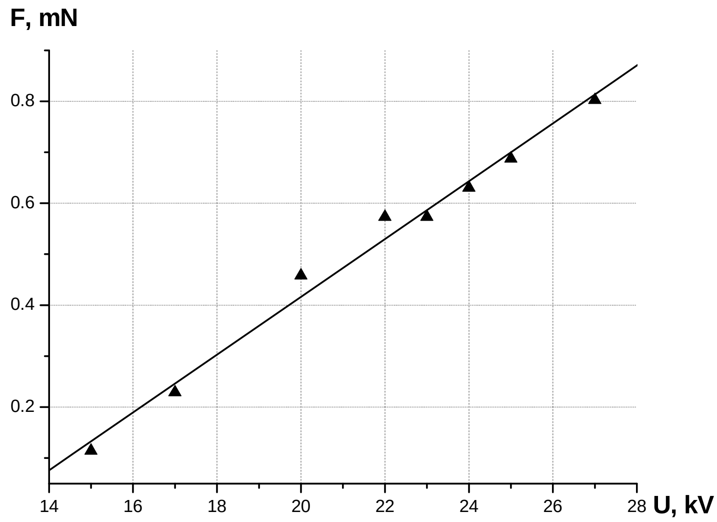


FIGURE 2b. Dependence of the force, acting on a ball with five needles, on its potential.

According to Fig. 2, $F_{gr} \sim U$, and according to formula (3) $F_{gr} \sim U^{-1}$. It can be provided if $D \sim U^2$. However the gradient force F_{gr} cannot be a unique reason of full indemnification for the Coulomb force, pushing away the charges. First, it is less than the Coulomb force, and, secondly, it falls down with distance R faster, than the Coulomb force. Therefore we should address to search other force which pulls charges together. This force can appear because leakage of charges from balls. In Fig. 3 a dependence of the force, acting on a ball, which has some needles thrust in it with spikes outside, at increasing of its potential, is shown. It is seen that at change of ball potential in 2 times (from 14 kV to 28 kV) a force, acting on it, increases in 8 times (from 0.1 mN to 0.8 mN). The reason of this force arising is pushing away of the charged ball from a cloud of the charges, which have left a ball. In a group of charged spheres these clouds will be located outside of group, and forces, pushing away the spheres from these clouds, will be directed opposite the Coulomb forces, pushing them apart. Let us assume that a positive ion with a charge e, which "has filtered" through a BL cover, will stick to a cluster, consisting of 1000 water molecules. A drift velocity v_{dr} of such cluster in electric field of intensity E is [11]:

$$v_{dr} = (eE/m_c N_a\, \sigma)^{\,1/2}. \qquad (4)$$

Here e = 1.6·10^{-19} C, m_c is a cluster mass, σ is a cluster cross-section, and N_a is air density. For a cluster of 1000 water molecules m_c = 3·10^{-23} kg, σ= 1.17·10^{-17} m^2. At N_a = 2.687·10^{25} m^{-3} v_{dr} = 0.1412·10^{-2} $(E)^{1/2}$. At BL charge Q = 10^{-3} C a cluster drift velocity at various distances R_{cl} from the BL centre is v_{dr} = 12.35/R_{cl} (m/s). Thus, drift velocity decreases with growth R_{cl}, and charges density n in the "cloud", on the contrary, increases with growth R_{cl}. Breaking a space near to BL on cells of thickness ΔR_{cl}, and considering, that charges are located in a column of radius a_b, we find quantity of charges in cell $N = n \cdot \Delta V_{cl} = n \cdot \pi a_b^2\, \Delta R_{cl} = \pi a_b^2\, \Delta R_{cl} \cdot R_{cl}$. A force of a cell charge with BL charge Q interaction is:

$$F_{cl}\,(R_{cl}) = eNQ/4\pi\varepsilon_0 R_{cl}^2 = ea_b^2 Q \cdot \Delta R_{cl} /\, 4\pi\varepsilon_0 R_{cl} \equiv A \cdot \Delta R_{cl} /\, R_{cl}. \qquad (5)$$

Directing ΔR_{cl} to zero and integrating (5) from R_{min} to R_{max}, we have:

$$F_{cl} = A \cdot \ln R_{cl}\Big|_{R_{\min}}^{R_{\max}}. \qquad (6)$$

Force F_{cl}, pushing away BL charge from a cluster cloud, does not depend directly on distance R_{cl} and there can be any. Fig. 3 shows, how the forces balance in a group of two BLs with identical charges Q = 10^{-3} C, which are surrounded by a cloud of charges, varies with a distance R. To the left of minimum F_s^2 at R = 2 m a force of BL Coulomb pushing away prevails, and to the right of minimum a force of BL pushing away from a cloud of charged clusters prevails. Position of balance (2 m) is comparable with a distance between two BLs in Fig. 1b.

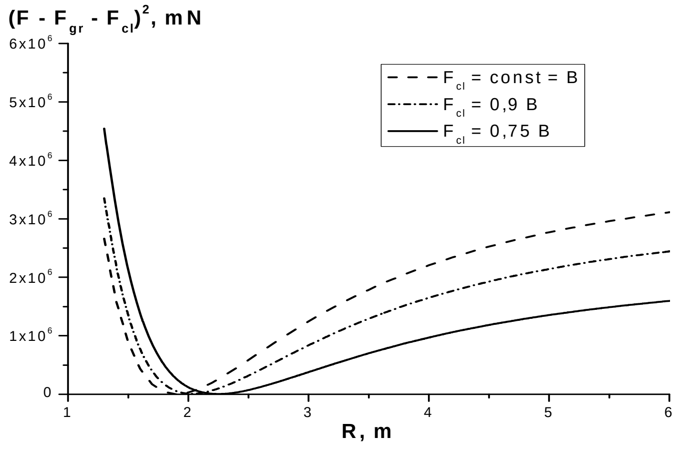


FIGURE 3. Dependence of a square of the forces sum $F_s^2 = (F_c - F_{gr} - F_{cl})^2$ on a distance R between two BLs with a charge of everyone $Q = 10^{-3}$ C. Function F_{cl} (R_{cl}) is considered a constant.

Thus, the configurations, consisting of several luminous objects, repeatedly observed in atmosphere, can be groups of BLs. A Coulomb pushing away of the BL charges of the same name is compensated by force of their pushing away from clouds of charged clusters. The groups, consisting of two, three, four etc. BLs, can be formed by the specified principle. At a great number of BL a group of objects can be perceived by the observer as a round object with windows.

1. W. Brand, *Der Kugelblitz*. Hamburg, H. Grand, 1923.
2. G. Egely, *Analysis of Hungarian Lightning Observations*, In: Progress in Ball Lightning Research. Ed. A.G. Keul. Proc. VIZUTUM. The Vizotum Project. Salzburg, Austria, 1993.
3. I.P. Stakhanov, *About Physical Nature of Ball Lightning*. Moscow, Nauchny Mir, 1996.
4. A.I. Grigoriev, *Ball Lightning*. Yaroslavl, YarGU Publishers, 2006.
5. V.A. Chernobrov, *Chronicles of UFO Visits*. Moscow, Drofa, 2003.
6. http://www.youtube/com/watch?v=yAvDC6BqbYQ.
7. *Crop Circles – Crossover from Another Dimension*, 2006. Toftenes Multivision a. s. Oslo, Norway, 2006. http://www.toftenes.no.
8. A.I. Nikitin, *An Electrical Capacitor as the Element of the Power Core of Ball Lightning*. Electrical Technology Russia, 1998, No 4, pp. 70-85.
9. A.I. Nikitin, *Electrodynamical Model of Ball Lightning*. Khimicheskaya Fizika, 2006, V. 25, No 3, pp. 38-62.
10. A.I. Nikitin, *Substance of Ball Lightning as a Certain Form of Unconventional Plasma*. Intern. Journ. Unconventional Electromagnetics and Plasmas (UEP). 2008. V. 1, pp. 101-108.
11. B.M. Smirnov, *Processes with Involvement of Small Particles*. Moscow, Logos, 2012.