LETTERS TO THE EDITORS

PACS numbers: 52.80.Mg, 92.60.Pw

Lightning ball: experiments on creation and hypotheses

(comment on "Energy density calculations for ball-lightning-like luminous silicon balls" by G S Paiva, J V Ferreira, C C Bastos, M V P dos Santos, A C Pavão)

G D Shabanov

DOI: 10.3367/UFNe.0180.201002h.0223

Abstract. **The problems addressed in this paper include estimating: the energy density of luminous silicon balls, the density range of a natural lightning ball, and whether and how the object created and described in the commented paper (*Usp. Fiz. Nauk* 180 218 (2010) [*Phys. Usp.* 53 (2) 209 (2010)]) corresponds to the natural phenomenon.**

V L Ginzburg believed that the problem of ball lightning (BL) would never be solved and the nature of its existence would never be elucidated until these objects were produced in a laboratory under clear control of all conditions and parameters [1]. An experiment devoid of a 'preconceived idea' is fruitless [2]. A quarter of a century ago there were more than a hundred preconceived ideas — hypotheses on the nature of BL [3], and at the present time they number more than two hundred [4], while the number of experiments in the production of BL is smaller by an order of magnitude. The paper by G S Paiva et al. [5] belongs to that rare type of paper in which BL is not only considered from the theoretical standpoint, but also accompanied by experiments. In this respect their paper stands among the commonly known papers, for instance, by Plante, J Barry [6], and Kapitza [7, 8]. However, in our view the paper has several drawbacks.

In the section "Results and discussions", Paiva et al. [5] considered the question of the diameter (D) of the spheres generated, on which the calculated energy density is critically dependent ($1/D^3$). Given for comparison in the paper is Table 1 for the energy density of natural BL, which ranges between 0.8 and 240 MJ m^{-3}. The apparent diameter of the glowing silicon spheres obtained by the authors is 2.5 cm, which corresponds to an energy density of 3.9 MJ m^{-3}. The resultant sphere energy density turned out to lie close to the lower limit of the interval of the values collected in Table 1. The authors noted that the diameter of the spheres in the pictures might well be estimated at 1 cm. The energy density would then amount to about 61 MJ m^{-3}, which is closer to the midpoint of the proposed energy density range.

G D Shabanov B P Konstantinov Petersburg Nuclear Physics Institute, Russian Academy of Sciences
188300 Orlovaya roshcha, Gatchina, Leningrad region, Russian Federation
Tel. (7-81371) 302 57. Fax (7-81371) 302 57
E-mail: shabanov@pnpi.spb.ru

Received 18 December 2009
Uspekhi Fizicheskikh Nauk **180** (2) 223 – 224 (2010)
DOI: 10.3367/UFNr.0180.201002h.0223
Translated by E N Ragozin; edited by A Radzig

In the calculation of energy density, use is also made of a better-determined figure — the mass of SiO_2 collected in the trail left by selected luminous balls, which averages to 7×10^{-3} g. Silicon oxide is generated from metallic silicon, which, as assumed in the paper, is in the form of aerogel (then, the initial silicon weight is evidently equal to 3.27×10^{-3} g). From these data it is possible to determine the density of the glowing sphere of the aerogel. If its diameter is assumed to be 2.5 cm, it would be three times lower in density than air and is bound to move upwards; if the sphere diameter is taken to be 1 cm, its density would be 4.8 times that of the air and it is bound to descend. As is evident from the video [9], upon production the silicon spheres fall to the floor and roll on it, which is an indication that the spheres are at least heavier than the air and the apparent diameter exceeds the true one. The author of Ref. [10] was also faced with the task of determining the diameter of glowing objects, which was similar to the task facing Paiva et al. [5]. The task was completed with the use of probe diagnostics [11] and earlier — for glowing objects produced by the technology of Ref. [10] — with the use of light filters in the work by S E Emelin [12] and then G Fußmann [13]. The certain similarity to G Fußmann's glowing plasmoids as regards the temperature of glowing spheres assumed in Ref. [5] calls for revision. As shown in Ref. [14], should glowing objects with a longer lifetime be made (by the technology of Ref. [13]), most of the time they would possess a low temperature approaching room temperature.

The data on energy density collected in Table 1 of Ref. [5] also need to be commented on. In S I Stepanov's paper [15], which is quite often referred to, the energy of BL proper (unrelated to other effects) is on the order of 100 J ('the average energy'). The average observed BL diameter is 23 cm (Table 10 from Ref. [16]), hence the average BL energy density is on the order of 0.016 MJ m^{-3}. On the other hand, the most thoroughly studied case of high-energy release by BL [17] yields a BL energy density of about 4000 MJ m^{-3}. It seems plausible that falling into this energy density range (0.016–4000 MJ m^{-3}) which spans a range of nearly six orders of magnitude, cannot be regarded as strong evidence that some process with a similar energy liberation bears a direct relation to the BL phenomenon.

The authors of Ref. [5] believe that the behavior of luminous silicon spheres (their falling to and rolling on the floor, bouncing upon impact with an obstacle, burning dielectric objects on contact, etc. [5]) is inherent in BL. We believe, in accordance with Refs [3, 4], that BL mostly flies (levitates) horizontally and evenly in 75% of the events of Ref. [3, 4], and 'falls from a cloud' in only 5% of the cases [4]. By the way, it is fairly easy to determine the fraction of natural

BL occurrences which the authors of Ref. [5] claim. Of the 25% of observations where BL does not levitate horizontally and evenly, it is necessary to select the events wherein the BL falls, rolls on the ground (floor), possesses a color temperature of about 4000 K, and is on the order of 1–3 cm in size. Natural BL with these properties would account for no more than 3%. Furthermore, natural BL very seldom interacts with dielectrics and bears little resemblance to a ball with a temperature of about 4000 K, which burns everything in its path as in Ref. [5]. Of the 500 eyewitnesses of BL who observed it from a distance of less than one meter, only 22 observers reported the occurrence of a heat flux from the BL [4]. From Ref. [5] it is hard to draw a conclusion as to whether the BL is safe or unsafe. Statistics [18] are available which indicate on the base of investigations of 6 thousand BL observations that personal encounters with BL entail injuries in 8.6% of the cases, of which 14.4% produce lethal outcomes. The data of these statistics suggest quite strongly that the main cause of trauma and death is due to the damage caused by electric current. In Refs [3, 4], the damage caused by electric current is stated to be a plain fact. Referring to Ref. [4]: "...we already have nearly as many as 6000 descriptions. ...Furthermore, BL possesses a large electric charge, and many cases of BL killing people and animals exactly through the electric charge have been reported. By and large it is valid to say that BL may create problems for the imprudent observer that are no less severe than those created by ordinary linear lightning, whose 'capabilities' are commonly known." Paiva et al. [5] make no mention of the electric properties of BL, perhaps because Refs [3, 4] were published in Russian and are not widely known among non-Russian-speaking researchers.

On the other hand, disregarding the bulk of observational data has a long-standing tradition. Usually this is advanced in the form of "one possible kind of a ball lightning" — A M Andrianov and V I Sinitsyn [19], or "for the first time Barry reproduced a phenomenon resembling ball lightning ...as... one kind, but by no means all kinds of ball lightning" ([6], pp. 166 and 172). V L Bychkov et al. [20] believe that "some natural ball lightning is organic in nature." In the foregoing we cited Refs [6, 19, 20], whose authors clearly saw a discordance between the properties of their experimentally produced luminous objects and those of the bulk of naturally observed BL. There are several hundred hypotheses concerning the nature of BL, and therefore we do not cite those which have not undergone experimental verification. The authors of Refs [5, 7, 8, 13] cited above, as well as S E Emelin et al. [21], L V Furov [22], G D Shabanov et al. [23], and A I Egorov et al. [24] evidently do not subdivide BL into kinds (types) and believe that their experimentally produced luminous objects and natural BL have identical mechanisms of formation and existence. The luminous objects produced in Ref. [5] under discussion might enter the category of "some kinds of BL," and their fraction might account for a certain percentage (the upper bound estimated for the fraction of BL occurrences after Paiva et al. [5]) in observational databases, if this division into kinds is possible at all.

Categorical statements have been made concerning the nature of BL, for instance, by Kapitza [7]: "We believe that the previously advanced hypotheses are unacceptable, because they are at variance with the energy conservation law." For N Tesla (1900), Ya I Frenkel' (1940) [25], P L Kapitza (1955), Barry ([6], p. 75), I P Stakhanov (1985), et al., BL was a single physical phenomenon with single physical nature. Stakhanov believed that contradictions would of course be eliminated by themselves if BL were treated as a package of dissimilar phenomena and different causes were suggested to explain the complex and sometimes contradictory properties of BL. However, an analysis of the statistically reliable database of BL observations, which were collected by Stakhanov according to a certain method, revealed, "...So far there are no grounds to doubt that ball lightning is a single phenomenon with single physical nature" [3].

Due to the work by Paiva et al. [5], the next possibility of interpreting BL as silicon ball lightning has been verified.

References

1. Ginzburg V L *Usp. Fiz. Nauk* **169** 419 (1999) [*Phys. Usp.* **42** 353 (1999)]
2. Poincaré H *O Nauke* (On Science) (Ed. L S Pontryagin) (Moscow: Nauka, 1983)
3. Stakhanov I P *O Fizicheskoi Prirode Sharovoi Molnii* (On the Physical Nature of Ball Lightning) 3rd ed. (Moscow: Nauchnyi Mir, 1996)
4. Grigor'ev A I *Sharovaya Molniya* (Ball Lightning) (Yaroslavl: YarGU, 2006)
5. Paiva G S et al. *Usp. Fiz. Nauk* **180** 218 (2010) [*Phys. Usp.* **53** 209 (2010)]
6. Barry J D *Ball Lightning and Bead Lightning: Extreme Forms of Atmospheric Electricity* (New York: Plenum Press, 1980) [Translated into Russian (Moscow: Mir, 1983)]
7. Kapitza P L *Dokl. Akad. Nauk SSSR* **101** 245 (1955)
8. Kapitza P L *Zh. Eksp. Teor. Fiz.* **57** 1801 (1969) [*Sov. Phys. JETP* **30** 973 (1970)]
9. Real Ball Lightning Created in the Lab, http://www.youtube.com/watch?v=KVDU-6opEqA&feature=fvw
10. Shabanov G D *Pis'ma Zh. Tekh. Fiz.* **28** (4) 81 (2002) [*Tech. Phys. Lett.* **28** 164 (2002)]
11. Shabanov G D, Sokolovskii B Yu *Fiz. Plazmy* **31** 560 (2005) [*Plasma Phys. Rep.* **31** 512 (2005)]
12. High voltage erosional water discharge, http://balllightning.narod.ru/hvewd.html
13. Versteegh A et al. *Plasma Sources Sci. Technol.* **17** 024014 (2008)
14. Shabanov G D et al. *Fiz. Plazmy* **35** 665 (2009) [*Plasma Phys. Rep.* **35** 611 (2009)]
15. Stepanov S I *Zh. Tekh. Fiz.* **60** (2) 211 (1990) [*Sov. Phys. Tech. Phys.* **35** 267 (1990)]
16. Smirnov B M *Usp. Fiz. Nauk* **162** (8) 43 (1992) [*Sov. Phys. Usp.* **35** 650 (1992)]
17. Dmitriev M T et al. *Zh. Tekh. Fiz.* **51** 2567 (1981) [*Sov. Phys. Tech. Phys.* **26** 1518 (1981)]
18. Grigor'ev A I *Ognennye Ubiitsy* (Fire Killers) (Yaroslavl: Debyut, 1990)
19. Andrianov A M, Sinitsyn V I *Zh. Tekh. Fiz.* **47** 2318 (1977) [*Sov. Phys. Tech. Phys.* **22** 1342 (1977)]
20. Bychkov V L, Bychkov A V, Timofeev I B *Zh. Tekh. Fiz.* **74** (1) 128 (2004) [*Tech. Phys.* **49** 128 (2004)]
21. Emelin S E et al. *Zh. Tekh. Fiz.* **67** (3) 19 (1997) [*Tech. Phys.* **42** 269 (1997)]
22. Furov L V *Zh. Tekh. Fiz.* **75** (3) 98 (2005) [*Tech. Phys.* **50** 380 (2005)]
23. Shabanov G D et al. *Khim. Fiz.* **25** (4) 74 (2006)
24. Egorov A I, Stepanov S I, Shabanov G D *Usp. Fiz. Nauk* **174** 107 (2004) [*Phys. Usp.* **47** 99 (2004)]
25. Frenkel' Ya I *Zh. Eksp. Teor. Fiz.* **10** 1424 (1940)