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Ball lightning observation in Mitino, the northwest district of Moscow

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The wide spread of digital video – camcorders, still cameras and smart-phones – has led to a great number of photos and videos with images of natural luminous objects in the web. Analysis of these images makes it possible to obtain data about their velocity, lifetime, and luminescence features, etc, which are usually lost at visual observation of these objects. However, in many cases one cannot extract from these photos information, concerning a distance to observed object and its size. This uncertainty decreases the value of such significant documents like a video-film about ball lightning observation in Dolgoprudny, shot in 2009 [1, 2].

Here we show a case of ball lightning observation where it was possible to overcome the specified uncertainty. These are video films of ball lightning movement in Mitino, shot simultaneously by three observers. This event occurred on July, 27th, 2015 when a west-east storm front passed over Mitino. A velocity of this front was about 100 km/hour. The luminous object which appeared above the forest to the west of Mitino was shot by three observers. The first of them, Egor Chichin (C), was in the house 34 in Baryshikha Street, which stretched along the edge of the wood [3]. The second observer, Vladimir Sokolov (S), was in the house 9 in Angelov lane [4]. The third observer, Dmitry Novosyolov (N), was making his video from the house 40 (building 1) in Baryshikha street [5]. Chichin shot the object with a smartphone HTC Desire 600 Dual Sim. He had been observing the object within 2-3 minutes before shooting and then he fetched the smart-phone and started recording. He said that before the shooting the object behavior had been the same as in the first half of his film – it was rushing about with amplitude up to 50 meters. Sokolov used video-camera SONY AV DCR-TRV33E. Before shooting he observed object during 2-3 minutes. During shooting a strong wind was driving in his face. The object appeared above the forest in the direction of Krasnogorsk, 5 km from Mitino. At first it was approaching to Mitino, and then began to move away from it against the wind. This attracted the attention of Sokolov, who understood, that the object didn’t behave like a balloon. Novosyolov shot the object with a phone Samsung Galaxy S4. One minute before he began the recording, he had noticed ball lightning, randomly moving from side to side. Duration of the video film of the first observer (C) is equal to 141 s, duration of the film of the observer

(S) is equal to 125 s, and the third observer (N) was shooting the object during 76 s. As follows from the stories of the eyewitnesses, a total time of ball lightning observation was 4-5 minutes. Two stages could be distinguished in the movement of ball lightning. In the first stage during 3-4 minutes (about one minute in video-records) it moved in the area of $3.5^0 \times 4^0$ at most, and in the second stage, lasting about one minute, it was rising to a cloud and was moving together with it in east direction. Chichin and Sokolov have shot both stages of ball lightning movement, and Novosyolov has shot only a stage of ball lightning lifting to a cloud. Fig. 1 is a map of Mitino area, where ball lightning was observed [6]. A distance CS defined on the map between the observers (C) and (S) is equal to 262±2 m, a distance NC between observers (N) and (C) is equal to 401.5±2 m, and a distance NS is equal to 321±2 m.

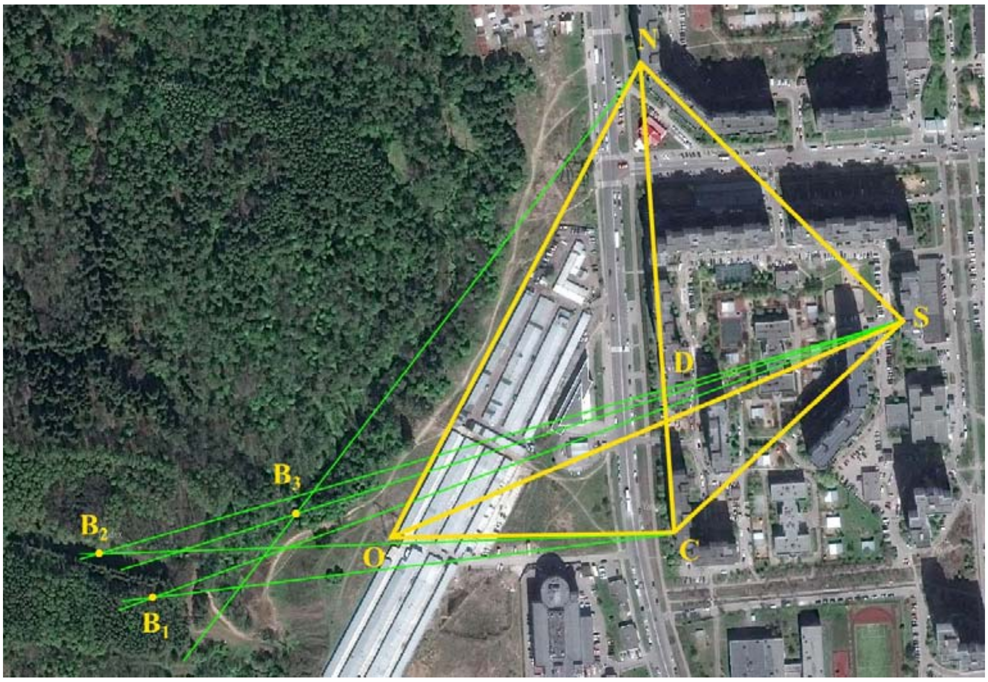

FIGURE 1. A map of Mitino district, in which ball lightning was observed [5]. The typical objects: (1) Parking house (Number 39, Baryshikha street); (2) Garages at the edge of the wood; (O) A transmission line tower; (D) Number 38, Baryshikha street; (B_1-B_3) – Spots of ball lightning position at minimum altitude; (C), (S) and (N) – the locations of observers.

In all films a transmission tower of a high-voltage line (O) is visible. Distances from this tower to the locations of three observers, accordingly, are equal: CO = 226.5±2 m, SO = 455.5±2 m and NO = 438±2 m. In triangles OSC and NOS all sides are known, it allows to define their angles. So, $\cos\angle OSC = (OS^2+CS^2-OC^2)/2\cdot OS\cdot CS = 0.9419$, $\angle OSC = 19.621^0$, $\angle SOC = 22.857^0$, $\angle SCO = 137.521^0$. In triangle NOS an angle $\angle NOS = 42.052^0$, $\angle ONC = 71.891^0$, $\angle NSO = 66.057^0$.

During the first minute ball lightning was moving as across a line of its observation, so as along this line. Let us choose for adjusting of time scales of three observers the moments (1) - (3), when ball lightning was at the minimum height above the ground. In Fig. 1 these positions of ball lightning are marked with letters B_1, B_2 and B_3.

In the Sokolov's film these events have occurred at (1) 20th, (2) 40th and (3) 80th seconds. Chichin has begun shooting for 32 seconds before Sokolov. In his film minima of ball lightning height were observed at (1) 51st and (2) 111.5th seconds. Unfortunately, in the Chichin's film ball lightning image is absent since 123rd till 157th second, therefore its last lowering (3) before the final ascending has not got to the film. This moment has got to the Novosyolov's film, who begun shooting 49 seconds later than Sokolov; it corresponds to 32nd second of its film. For definition of spatial scales we have chosen the house 38 in Baryshikha street, which distance SD to the observer (S) is equal to 202±2 m, and a transmission line tower (O), which height was assumed to be 28 m [7]. As a scale we have chosen in the image of the house 38 a distance between the floors, equal to 2.8 m [8]. For the first minimum (1) (S) we find, that in a plane a wall of this house ball lightning is displaced to the right from the tower centre at the distance 6.69 m. From here $tg\llcorner OSB_1 = 0.0331$ and $\llcorner OSB_1 = 1.90^0$. The second minimum (2) is displaced to the right from the tower centre at distance 16.30 m, $tg\llcorner OSB_2 = 0.081$ and $\llcorner OSB_2 = 4.61^0$. Horizontal displacement from the tower of a point of the third minimum (3) is equal to 12.69 m, $tg\llcorner OSB_3 = 0.063$ and $\llcorner OSB_3 = 3.59^0$. In the 51st second of the Chichin's film the position of the first minimum of ball lightning height (1) is displaced to the left from the tower centre (O) at distance 23 m. Distance from the observer (C) to the tower is CO = 226.5 m, from here $tg\llcorner OCB_1 = 23/225.5 = 0.101$ and $\llcorner OCB_1 = 5.798^0$. In the position (2) a distance from ball lightning to the tower centre is 4.4 m, from here $tg\llcorner OCB_2 = 4.4/225.5 = 0.0194$ and $\llcorner OCB_2 = 1.113^0$. In the Novosyolov's film ball lightning in position of the minimum (3) is observed at 32nd second, it is displaced to the right from the tower centre (O) at a distance $\Delta x = 61.52$ m. Distance NO = 438 m. From here $tg\llcorner ONB_3 = \Delta x / NO = 0.14$ and $\llcorner ONB_3 = 7.99^0$.

In triangle B_1CS an angle $\llcorner CSB_1 = \llcorner CSO + \llcorner OSB_1 = 21.519^0$; $\llcorner SCB_1 = \llcorner SCO + \llcorner OCB_1 = 143.319^0$; $\llcorner SB_1C = 15.161^0$. In triangle B_2SC an angle $\llcorner CSB_2 = \llcorner CSO + \llcorner OSB_2 = 24.234^0$; $\llcorner SCB_2 = \llcorner SCO + \llcorner OCB_2 = 138.634^0$; $\llcorner SB_2C = 17.132^0$. In triangle B_3SN an angle $\llcorner NSB_3 = \llcorner NSO - \llcorner OSB_3 = 62.463^0$; $\llcorner SNB_3 = \llcorner SNO + \llcorner ONB_3 = 79.886^0$; $\llcorner SB_3N = 37.651^0$. Knowing angles of triangle B_1CS and a length of side CS = 262 m, we can find distances from observers (C) and (S) to ball lightning. $CB_1 = (CS \cdot \sin\llcorner CSB_1)/\sin\llcorner SB_1C = 367.46$ m and $SB_1 = (CS \cdot \sin\llcorner SCB_1)/\sin\llcorner SB_1C = 598.41$ m. From triangle B_2CS: $CB_2 = 365.07$ m, $SB_2 = 587.78$ m. From triangle SB_3N: $SB_3 = (NS \cdot \sin\llcorner SNB_3)/\sin\llcorner SB_3N = 517.33$ m, $NB_3 = 465.97$ m. In Fig. 1 positions of ball lightning on the district, defined on the basis of our calculations, are shown. One can see that ball lightning in the point B_3 is removed from the transmission line at 70 m.

Now let us try to define ball lightning height over the ground. A roof height of the 14-storeyed house 38 in Baryshikha street H_D = 42.6 m, and its width is 13.8 m [8]. The observer (S) is located above the roof of this house, and for him the distant wall of the roof seems above the near one at 0.3 m. An angle between a plane of the roof and a ray of his sight is α = arctg 0.3/13/8 = 1.3^0. On the basis of this one can conclude, that he was raised over the roof at height ΔH_S = tg $\alpha \cdot SD$ = 4.6 m, so he was located at height $A_S = H_D + \Delta H_S$ = 47.2 m. Let us accept for a level of height reading in the Sokolov's film a height of superstructure – a roof of the lifts engine room, equal to 44.35 m [8]. In the position (1) in a plane of wall of the house 38, ball lightning is above a superstructure roof at 1.32 m. In the position (2) it is below the superstructure roof level at 0.62 m, and in the position (3) it is below this level at 1.06 m. Thus, the apparent values of ball lightning heights are equal to h_1 = 45.67 m, h_2 = 43.73 m and h_3 = 43.29 m. The observer (S) is above the calculated height values at $\Delta h_1 = A_S - h_1$ = 1.53 m, $\Delta h_2 = A_S - h_2$ = 3.47 m, Δh_3 = 3.91 m. Ball lightning altitudes over ground level can be found from the formula: $H_n = A_S - (\Delta h_n \cdot \mathrm{SB}_n)/\mathrm{SD}$ (n = 1, 2, 3). Substituting in this formula numerical values of sizes, we find H_1 (S) = 42.67 m, H_2 (S) = 37.71 m and H_3 (S) = 37.19 m. In the Chichin's film the minimum (1) of ball lightning height is observed at the 51st second. Accepting a tower height equal to H_O = 28 m, we find that at this moment in a plane of the tower, ball lightning was above its top at h_1 (C) = 13.5 m, that is H_1 (C) = H_O + h_1 (C) = 41.5 m. Let a height of the observer (C) over the ground level A_C (1) was slightly less than H_1 (C). A distance from him to the tower was CO = 226.5 m, and a distance to ball lightning was CB_1 = 367.5 m. Let us accept for true value of ball lightning altitude a value H_1 (S) = 42.67 m, this is more than H_1 (C) at 1.2 m. The tangent of an angle β of inclination of the straight line, drawn through points of heights H_1 (S) and H_1 (C), to a horizontal plane is [H_1 (S) – H_1 (C)] / (CB_1 – CO) = 0.0085. From here one can find a downwards displacement of the observer (C) position from the horizontal plane, drawn at height H_1(C), Δh_C (1) = CO·tg β = 1.9 m and a height of observer A_C (1) = H_1 (C) – Δh_C (1) = 39.6 m. Because the height of the observer (C) over ground level in the location of the house 34 in the Baryshikha street was no more than A_C = 33.5 m, this means, that the level of the house 34 basis may be above the tower (O) basis at 6.1 m. In the position of the second minimum (2) (71st second of the Chichin's film) in a plane of the tower, ball lightning was at a height 38 m, and at a distance CB_2 = 365 m its true height was H_2 (S) = 37.71 m. Performing calculations similar stated above, we find, that in this case the observer (C) was at height A_C (2) = 38.5 m. This within an error of measurements coincides with height A_C (1).

Let's define ball lightning height in position of last minimum (3) on the basis of the Novosyolov's film. At the 31.5th second of the film, in the tower (O) plane, its distance to tower top is equal to 10.4 m, and to the earth – to 38.4 m. Distance from the observer (N) to the tower NO = 438 m, and distance NB_3 = 466 m. Thus, ball lightning height is H_3 (N) = 40.8 m. This is at 3.6 m more than H_3 (S) = 37.19 m. This can be connected with heights distinction of the bases of the house

40 in the Baryshikha street and tower (O). Thus, definition of ball lightning height on the basis of the analysis of films of three observers leads to practically identical values. However because of strong influence of land relief on calculations results, the analysis, made on the basis of the film of the observer (S), is more reliable.

Let's estimate a velocity of ball lightning ascending. In the Sokolov's film at t_S = 9 s (since 80th till 89th second) in the plane of the house 38 it displaced upwards at Δl_S = 16.65 m. A real displacement of the ball, which at the start of lifting was at distance SB_3 = 517.3 m from the observer, is $\Delta L_S = (\Delta l_S \cdot SB_3)/SD$ = 42.64 m. From here its velocity is $v_v(S) = \Delta L_S / t_S$ = 4.74 m/s. In the Novosyolov's film in the initial phase of lifting during t_N = 11 s (from 33rd till 44th second) ball lightning in a plane of the tower, located at a distance NO = 438 m, has risen upwards at Δl_N = 49 m. A real displacement of ball lightning, removed from the observer (N) at distance NB_3 = 466 m, was ΔL_N = 52 m, and a velocity of its ascending was $v_v(N) = \Delta L_N / t_N$ = 4.74 m/s. According to the Chichin's film, ball lightning begun lifting to a cloud at the moment t_0 (C) = 111.5 s and has touched an edge of a wall of his house at t_f (C) = 136.6 s. Thus during 25.1 s it has passed the way B_3C = 296 m. From here a velocity of its horizontal movement is $v_g(C)$ = 11.8 m/s. In the Sokolov's film an interval between the beginning of ball lightning lifting and the moment of its hiding behind a house wall is equal to 42.5 s. Considering the distance B_3S = 517.3 m, we find $v_g(S)$ = 12.1 m/s. For definition of full ball lightning velocity let us add vectorially the velocity v_g = 12 m/s and the velocity of its vertical movement v_v = 4.7 m/s, as a result we find v = 19.9 m/s.

On shots of the Sokolov's film ball lightning during periods of its being at the minimum height, in a plane of the house 38 wall, looks as a disk with dim edges with a diameter about 0.25 m. Considering that distance SB_n is more than distance SD in 2.94 times, we find a real diameter of the ball 0.73 m. Estimation of ball lightning diameter on the basis of the Chichin's and Novosyolov's films results approximately the same size (but with a greater error). One can also estimate a ball lightning diameter, knowing time for which the ball after a touch a wall disappears behind it. In the Sokolov's and Chichin's films this process takes less than two shots, that is it lasts nearby 0.06 s. Multiplying this interval on the velocity of horizontal movement of ball lightning v_g = 12 m/s, we find its diameter 0.72 m.

In this paper we have focused on the description of the methods for determining the sizes of short-living natural luminous objects and the distances to them. In future we are going to clarify the details of ball lightning motion in Mitino and also to find out how the electric fields, generated by storm clouds and transmission lines, affect this motion.

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