Ball lightning

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Version 1 30 September 2023; Version 2 18 March 2024

Observation

- https://www.youtube.com/watch?v=F6m5kc0d2Y0 copyright © City Montessori School 2023 (low resolution version).
- Video clip showing the occurrence of indoor ball lightning during a heavy thunderstorm in the early morning of Monday 11 September 2023. This was recorded by an unmanned fixed CCTV security camera in the lobby of City Montessori School (CMS) Golf City campus, Lucknow, India. First observed by Mr Nitish Arora, Golf City campus Admissions Officer.

Video log

06:58:30 Continuous heavy rainfall may be seen through the right-hand glass door. Lightning flashes and/or automatic adjustments of the camera aperture result in frequent fluctuations in the video brightness.
06:58:40 Lightning flash.
06:58:45 Ball lightning appears on the extreme right, near the bottom of the glass door, moving left slowly.
06:59:17 Ball lightning departs the field of view on the extreme left.
06:59:32 Ball lightning reappears on the extreme left, moving right quickly.
06:59:38 Ball lightning moves aimlessly in the vicinity of the right-hand glass door.
06:59:56 Ball lightning departs the field of view on the extreme right, but its continued presence in the lobby can be inferred from its faint reflection in the right-hand glass door which moves slowly in the vicinity of the lobby front desk.
07:00:25 Reflected image fades from view.
07:00:57 School employee appears through doorway top left, clocks in.
07:01:09 School employee departs through the same doorway.
07:02:01 Lightning flash?
07:02:47 School employee appears through doorway top left, moves rightwards across lobby.
07:02:56 School employee departs through doorway top centre in the field of view.
07:03:38 A fluctuation in the video brightness, accompanied by the appearance of a faint moving image similar to that of 06:59:56 in form and location.
07:03:42 School employee appears through doorway top centre; faint image still present.
07:03:55 School employee departs through doorway top left; faint image still present.
07:03:58 School employee reappears through doorway top left; faint image still present.
07:04:10 School employee departs through doorway top left; faint image still present.
07:04:18 Ball lightning appears on the extreme right, near the bottom of the glass door, moving left slowly. Clearly the attendant faint image is its reflection in the glass door.
07:04:52 Ball lightning departs the field of view on the extreme left.
07:05:00 Ball lightning reappears on the extreme left, moving right quickly.
07:05:07 Ball lightning moves aimlessly in the vicinity of the right-hand glass door, tracked by its reflection.
07:05:16 Ball lightning departs the field of view on the extreme right, but its reflection continues to move slowly around the bottom centre of the field of view.
07:06:00 Reflected image fades from view, after which there are no further observations that may be associated with ball lightning.

Vaporised silicon hypothesis

- Reference https://en.wikipedia.org/wiki/Ball_lightning and associated links.
- The school lobby is adjacent to a cloistered quadrangle in which there is an 89' square astroturf play area. Astroturf is made of a variety of carbon-based polymers, sprinkled with small grains of rubber (also carbon-based), and bedded on a layer of fine sand (silica, SiO_2).
- If lightning were to strike one or both of the 8' iron poles (for the hanging of a volleyball net) in the astroturf play area then all of the ingredients are present for the reaction $SiO_2 + 2C +$ electric arc $\rightarrow Si + 2CO$, resulting in concentrations of vaporised Si in the air above.

Ball formation

- Let us suppose that vaporised Si is present in the air above the quad astroturf, and that some of it enters the school lobby via a ½"-wide vertical gap between a doorframe and the wall.
- This highly-reactive Si vapour will quickly remove all of the adjacent O_2, generating an O_2 concentration gradient which acts as a central force, morphing the remaining Si vapour into a regular sphere or ball.
- Since the atomic masses of Si and N_2 are very similar (28.0855 and 28.0134 respectively), once all of the O_2 in the ball has been used up then its density will be uniform and quite distinct from that of the surrounding air, with the effect that the ball will move as if it is a whole and indivisible body, that is, a solid.

Ball chemistry and dynamics

- $Si + O2 \rightarrow SiO_2$ is exothermic, so as the ball continues to react (at a rate determined by its spherical surface area) it will gain heat and rise through the air as a single body.
- As it rises the ball moves towards a gap above a sliding door near to the camera which (relative to other points nearby) is an enhanced source of O_2.
- As the Si reacts with O_2 the proportion of SiO_2 in the ball increases, so its total mass also increases.
- Eventually the weight of the ball (resulting from its increasing mass) exceeds its buoyancy (resulting from its distinct density and temperature) and it sinks back down to the ground, where again its main source of O_2 is the gap beside the door by which it entered the lobby.

Ball depletion and decay

- As the Si continues to react it becomes depleted, the ball cools a little, and some of the SiO_2 'rains out', allowing the rise-and-fall cycle to occur once more.
- Alternatively, another lightning strike, possibly at 07:02:01, may have generated a second ball, which, having similar characteristics, repeats the movements of the first.
- But in either case the vaporised Si is eventually depleted to the extent that the ball loses integrity and dissipates altogether.

Wavelength calculation

- The standard enthalpy of formation of SiO_2 is $\Delta_f H = -911$ kJmol^{-1}. If this energy is emitted as electromagnetic radiation then it corresponds to a wavelength $\lambda = 130$ nm (nanometres).
- This calculation utilises the Avogadro law $E = \Delta_f H/N_A$ J, the Planck equation $\nu = E/h$ s^{-1}, and the wave formula $\lambda = c/\nu$ m, where the Avogadro constant $N_A = 6\ 10^{23}$ mol^{-1}, the Planck constant $h = 6.6\ 10^{-34}$ Js, and the speed of light $c = 3\ 10^8$ ms^{-1}. E is energy and ν is frequency.
- A wavelength of 130 nm is in the far-ultraviolet (far-UV) range, which is barely-visible to the human eye. Nevertheless it may be within the detectable range of the CCTV camera. If so then this would explain how the ball lightning was seen on the video but did not catch the attention of the school employee who was in the school lobby at the same time (that is, in the period 07:03:42 – 07:04:10, when from his standpoint it was moving around in the far corner).

Experiment

- In order to investigate the implications of this wavelength calculation I conducted the following experiment. With the help of CMS Head Office colleague Vijay Tiwari I obtained a Philips TUV 8W G8T5 UV-C air and water disinfection lamp which emits monochromatic light at wavelength 254 nm (that is, closer to the 400-700 nm visible range than the 130 nm associated with ball lightning, but still within the UV range of interest). Then on 16 March 2024 we set up this lamp in the lobby of CMS Golf City campus in order to view it using the same CCTV camera that had detected the ball lightning six months earlier. Also for comparison we separately viewed the appearance of a 40 W incandescent clear-glass lightbulb. These investigations were conducted between 6:30am and 7am, that is, 15-45 minutes after sunrise; whereas on 11 September the ball lightning had been observed 70-80 minutes after sunrise, albeit with darker skies because of the thunderstorm. Selected CCTV video clips were extracted by Nitish Arora, Golf City campus Admissions Officer, who had noticed the ball lightning in the first place. Also present was the school employee who had appeared in the 11 September video, Golf City campus Physical Training Instructor Dominic Mendonsa.
- Figures 1a-4a are stills from the colour videos obtained on 16 March, and Figures 1b-4b are their black-and-white equivalents (for comparison with the original ball lightning video which is available in black-and-white only). Figure 1a/b shows the lobby field-of-view with the UV lamp switched on for the first time. Figure 2a/b shows that even when the UV lamp is held close to an obstacle, in this case a portable electric socket board, it casts no visible shadow. This is in stark contrast with the 40 W incandescent lightbulb which when held in the same position casts strong shadows in every direction, see Figure 3a/b. Meanwhile a video taken by Vijay on his mobile phone shows that, instead of a shadow, the UV lamp produces the equivalent of the ‘faint reflection’ first seen on 11 September at 06:59:56. Figure 4a/b is a still from Vijay’s video which shows two reflections, one a diffuse patch on the polished coffee table between the lamp and the camera, and the other a faint line apparently on the side of the lobby front desk. The second of these is of more interest to me because it appears to be an image of the lamp as reflected in the glass door in the corner behind the lamp, just like the ‘faint reflection’ observed on 11 September. However it is not entirely clear to me whether the image is visible because it is cast upon a surface (in this case the side of the lobby front desk), or whether it is an optical ‘flare’ or ‘ghost’ resulting from the complex arrangement of lenses in the camera, such that it appears to be hovering ‘in thin air’. But in either case this image is clearly associated with the UV lamp, and nothing like it was seen when the 40 W incandescent lightbulb was used.
- It is clear from these stills (and from their source videos) that the UV lamp readily produces two unusual optical effects, which also are seen on the ball lightning video, but which are not seen with conventional/familiar light sources: (i) the presence of faint but coherent reflections; but (ii) the absence of distinct or coherent shadows. Accordingly these observations support the suggestion that the ball lightning is emitting in the UV range, which in turn supports the vaporised silicon hypothesis as the basis of the ball lightning phenomenon.

Significance

- Web searches reveal several other videos purporting to show ball lightning, but none of them match the quality and authenticity of that recorded on the early morning of 11 September 2023 at CMS Golf City, Lucknow, India, and subsequently observed and reported by Nitish Arora.
- Accordingly I propose that henceforth ball lightning is also known as ‘Arora’s Aurora’.

Acknowledgments

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Figure 1a

Figure 1b

Figure 2a

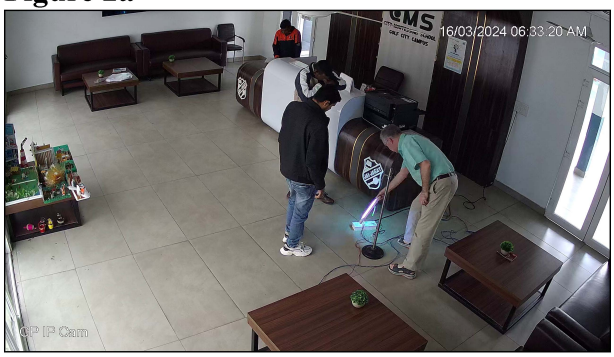

Figure 2b

Figure 3a

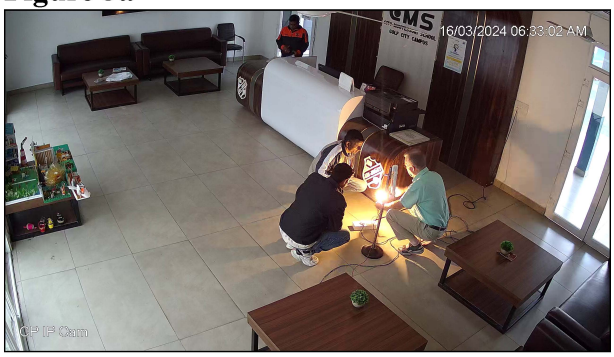

Figure 3b

Figure 4a

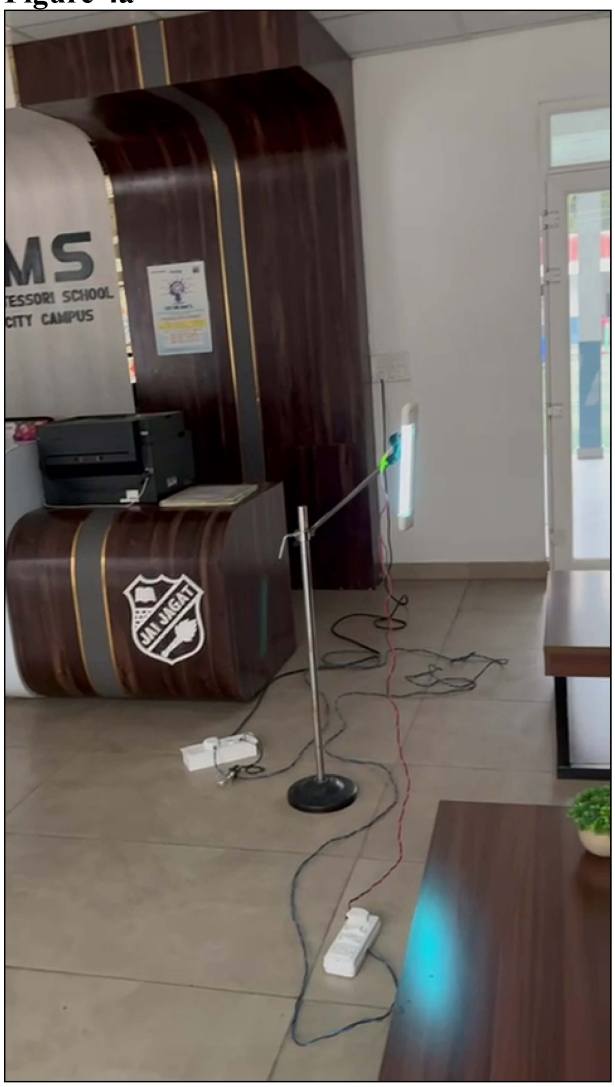

Figure 4b