

4.3

Ball Lightning and Earthlights¹

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Introduction

Even a cursory review of the literature shows that the subjects of ball lightning (BL) and earthlights (EL) have remained highly controversial within the field of physics for many decades. This has been for various reasons not least of which is the difficulty in collecting data in forms that scientists demand. So far neither is irreproducible. Nevertheless, this controversy has only seemed to generate greater levels of creativity in proposing new explanatory hypotheses.² Of course it is possible that more than one phenomenon has been grouped together incorrectly which would only contribute to this dilemma (Arago, 1838, 1854; Barry, 1980; Charman, 1979; Ohtsuki, 1989; Uman, 1968; Smirnov, 1993). Another fact seems to emerge from a review of this large and still growing body of literature, viz., that there have been enough reports made by reliable observers to suggest that they are phenomenon occurring naturally. Ball lightning is very likely a product of thunderstorm dynamics.³ Indeed, the diurnal frequency of thunderstorms is reasonably positively correlated with the frequency of BL sightings (Fryberger, 1994; Singer, 1971). Finally, a number of useful bibliographies have been published for those who may want to study these phenomenona further (Bateman, 2008; Carbognani, 1999; Library of Congress, 1961). Another useful reference is: <http://en.wikipedia.org/wiki/Lightning>.

To the extent that ball lightning is spherical and occurs at various altitudes it is relevant to this report not only because it might be misidentified with qualitatively different spherically shaped visual phenomena (herein referred to as UAP) but also for reasons of flight safety. The

¹ Boules de feu, Éclair en boule, Foudre Spherique (French); Kugelblitz (German); *ZHAROVAYA MOLNEYA* (Russian); *KYLOVA BLUSKAVKA* (Ukrainian); Relampagos Globulares; Bola de fogo, Raios-Bola (Portuguese); Hitodama (Japanese); Kulelyn (Norwegian); Rayo globular, descarga esferica, Bola de fuego (Spanish). Also see 2.2.

² The list of such hypothesis is long indeed ranging from alleged ultra high frequency (standing) waves causing an electrodeless discharge between earth and cloud to thunderstorm-induced protons that might produce a nuclear reaction yielding radioactive isotopes of fluorine and oxygen whose decay into positrons and gamma rays would provide the energy for ball lightning, to “fluffy balls” of burning silicon generated by “ordinary” lightning, among others.

³ This is not to say that BL is only seen during thunderstorms; occurrences also been reported in clear weather (Egely, 1989)

next section presents aircrew and passenger reports - of what was interpreted as BL - over many decades and altitudes. To what degree do these reports differ from those to which the label UAP has been assigned? Or, put another way, can aircrew accurately discriminate between BL and UAP, assuming that they are in fact independent phenomena?

Pilot Reports of BL-Like Phenomena Seen at Various Altitudes

We will begin with what has become a classic review of BL by Singer (1971) who devoted four pages (Pp. 38 – 42) to incidents of fireballs and airplanes in flight. He presented nine narratives from flight crew or passengers on board that are summarized in Table 1.

Table 1

Recorded Ball Lightning Interactions with Airplanes in Flight
from Singer (1971)

Date	A/C Type	Flight Data	Ball Lightning Data
1938	BOAC Flying Boat	2,500m, in dense nimbostratus cloud	Fireball entered through his "open cockpit window". It traveled through length of plane before exploding. No damage was reported.
1948	TWA	3,400m, dense cloud	Small (3" diam.) firey orange-yellow center with dark gray-violet layer and short spiral tail seen outside airplane and moving at same speed. It suddenly "burst" thirty cm from side of airplane and emitted a 3 m long bright ray in forward direction (with loud detonation).
1948	Military A/C	Cloudy sky	Airplane crashed with no survivor(s). A large fireball exploded in sky and credited with the airplane's destruction by authorities.
1956	Russian LI-2 transport	3,300m, cumulo-nimbus	25-30 cm diam. orange-red fireball approached A/C from front. Suddenly swerved to left within 30-40 cm from nose. It struck propeller tip and exploded in loud and blinding white flash. (Altschuler, 1968)
1956	Russian jet	2,500m, storm cloud	Fireball first seen in right-front of nose. It exploded into fragments with loud noise and bright flash. Nearest engine stopped but was restarted in flight. No visible damage found. Flameout explained by rarefaction from the

explosion.

1959	Russian	>4,000m, dense cloud	Lightning bolt seen in front of airplane and simultaneous "strong blow jarred" it. A 10 cm fireball passed on left side with shower of sparks. Cabin was strongly magnetized with 100 deg compass error. Radio operated but radiocompass malfunctioned. Rivets melted on left-front of fuselage; skin not destroyed.
1960	U.S. KC-97	5,400m, in cloud	45 cm yellow-white ball entered cockpit through windshield, passing between four flight crew and progressing to rear in 3 seconds time. It exited the fuselage onto right wing and then into cloud.
1963	U.S. commercial plane	flying through electrical storm	Sudden loud bright flash, then (est.) 22 cm blue-white sphere passed at constant height down length of cabin at 1.5 m/sec velocity; spherical; no toroidal structure; slightly darker edge; about equivalent to 5 - 10 w lamp; no heat felt.
1965	Russian, LI-2	thick nimbostratus	Airplane struck by 60 - 80 cm fireball and loud "rifle shot" sound heard. "Red streaming discharges" traveled over fuselage. Radio compass rotated and magnetic compass spun erratically for 3 - 5 minutes. It was incorrect when it stopped rotating. All radio equipment malfunctioned also. Several rivets damaged in nose and two small holes (1.5 - 2 cm) melted in trailing edge of the elevator.

In his summary of these events Singer (op cit., pg. 42) states that ball lightning is "clearly established by these several reports which also indicate potential hazards, e.g., explosions, temperatures high enough to melt metals, strong electrical effects, and force sufficient to deflect the craft from its path." It is also important to note that Singer did not include any so-called "foo-fighter" aircrew sightings from WW-II in his review despite the fact that their visual characteristics are, in several respects, similar to those of BL (Roberts, 1990; www.wikipedia.org/wiki/Foo-fighter, <<http://www.science-frontiers.com/sf083/sf083g10.htm>> It also may be mentioned that Chapter 10 in (Rakov and Uman, 2003) is devoted to Lightning and Airborne Vehicles.

Additional In-Flight Accounts of "Alleged" Ball Lightning

1952. A student Air Force pilot and instructor were flying a T-33 jet trainer near Moody AFB, Georgia in 1952. They were instructed to divert to Mobile, Alabama because of a thunderstorm.

Flying at 4,000 m altitude he suddenly collided with a "big orange ball of fire" that struck the nose of his airplane; the student believed that they had had a mid-air collision with another airplane. Their low frequency compass system failed and they had to proceed to another base using only their radio to a ground controller. Upon landing it was discovered that the compass electronics in the airplane's nose was melted; there were no other holes or marks found on the airplane. Everything functioned normally after replacing the radio compass. (Altschuler, pg. 733, 1968)

Approx. 1955. "This is not really my observation or experience, but my fathers. My father was a fighter pilot during Korea and Vietnam, and later flew diplomats in DC-6's. He has seen some PRETTY weird stuff during his time in the sky... He was flying the DC-6 (MIL version), IFR (instrument flight rules) and they were preparing to navigate around or through a thunderstorm. My dad, flew the plane through a cloud, and the aircraft was struck by lightening! The old man (as I call him affectionately) said the lightening bolt hit the nose of the aircraft, and a ball of what he describes as "pure energy" passed down the nose, through the glass into the cockpit, passed my dad, the co-pilot, and navigator, and continued down the center aisle, to the rear of the aircraft and disappeared, (sic) presumably out the end of the plane. There were no injuries or instrumentation failure. Just the obvious human error caused by the dumbfounded aircrew. Anyway, this relates to lightening balls, and thought your readers may be interested in this phenomenon."
Submitted: July 26, 2003 at 17:31:28 (PDT) <<http://amasci.com/weird/unusual/bl.html>>

March 19, 1963.⁴ Physicist Richard Jennison wrote the following account of a BL-like phenomenon to Nature (1971). "I was seated near the front of the passenger cabin of an all-metal airliner (Eastern Airlines Flight EA 539) on a late night flight from New York to Washington. The aircraft encountered an electrical storm during which it was enveloped in a sudden bright and loud electrical discharge (0005 h EST). Some seconds after this, a glowing sphere a little more than 20 centimeters in diameter emerged from the pilot's cabin and passed down the aisle of the aircraft approximately 50 centimeters from me, maintaining the same height and course for the whole distance over which it could be observed." He also noted that it was blue-white and did not radiate any heat. It moved along at a "walking pace" about 2.5 feet above the floor.

November 1, 1963. "An Eastern Airlines plane was struck by a ball of lightning while flying through a storm over Atlanta, Georgia on November 1, 1963. The pilot reported smoke in the cockpit and the smell of ozone. Upon landing, investigators found an 18" section of the rudder lost, a hole in the radome, and burn spots on various parts of the fuselage."
<www.stormtrack.org/forum/archive/index.php/t-5772.html>

Mid 1960s. "This happened in the mid 1960s. I had just taken off in a C-130 heading for Berlin taking a group of Army Rangers to the city. There were no thunderstorms in the area but there was a solid overcast at about 2,500 feet. As were about to enter the overcast there was a loud bang and seconds later the Loadmaster reported that a ball of fire had rolled down the cargo compartment and went out the back of the aircraft. No damage at all to the rear cargo door. However, a hole was blown in the radar (cowling) in the nose about the size of a soft ball. The radar was totally fried. After we landed at Templehof I questioned the Rangers and they all

⁴ www.daviddarling.info/encyclopedia/B/ball-lightning.html

had the same story. They were sitting along the fuselage on both sides of the aircraft and the ball went right in front of their feet. The raydome and the radar had to be replaced."

Submitted: May 30, 2004 at 06:06:57 (PDT) <<http://amasci.com/weird/unusual/bl.html>>

Winter 1971. "In the winter of 1971 I was piloting a B-52 aircraft on a mission over northern Canada . We were flying an airborne alert mission. It was probably about 10 PM with a quiet time in the aircraft although we could see some weather activity off in the distance. In the forward part of the cockpit were myself and my co-pilot. Suddenly, without warning a ball of fire or energy about the size of a softball appeared to come right through the windscreen, roll between me and the co-pilot, over the throttle pedestal and toward the rear of the cockpit ... As I tried to follow it over my shoulder it just disappeared. It rolled about 10 feet from the windscreen until it disappeared. Both myself and my co-pilot let out expletives as we saw the ball appear and then again after it disappeared. The co-pilot was very shaken and said let's land this thing. Fortunately I had heard somewhere about the ball lightning phenomena so I guessed that's what we saw. There was no physical damage to the aircraft, no electrical damage nor any evidence that it had occurred. When we landed, I wrote it up in the debriefing book but never heard of any damage that had been caused nor did anyone question me about it later."

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Summer 1979. "In the summer of 1979, while flying south, at 3-5,000 feet, in our Cessna 172, over a reporting tower called ONTARIO, just north of the Los Angeles area, I noticed a ball of lightening about 2-1/2 to 3 feet in diameter, come up to the co-pilot (my) side of our plane, about 3 or 4 feet away from my window, and sit there for about 30 seconds. I yelled at my husband, who was piloting the plane, to contact the tower and ask if they had seen the same thing on their radar, but the lightening ball must have cut out the frequency, as he could not get through. It was a very clear day, and after the ball of lightening ? (sic) disappeared, I begged my husband to report it, once we made a connection again, but he wouldn't. I think he thought they would think we were crazy. Of course I thought it was a UFO. It was not until several years later, when my class was reading a story about Barney and Betty Smith,⁵ (sic) that I told my class "my" UFO story. It was then that a very bright boy suggested it was NOT a UFO, but was probably an instance of St. Elmo's fire, which it may well have been. Still, today, the memory of the instance is as real as if it were yesterday."

Submitted: May 27, 2006 at 12:26:05 (PDT) <<http://amasci.com/weird/unusual/bl.html>>

January 15, 1984. A TASS News Agency article described how a 4 inch diameter ball of fire appeared on the outside fuselage in front of the cockpit of an Ilyushin-18 airplane that was flying very near a thunderstorm over the Black Sea. The BL disappeared with a deafening noise, then it reappeared in the passenger cabin several seconds later where it floated above the heads of the passengers. Upon reaching the rear of the airplane it split into two "flowing crescents" that joined together and (apparently) exited the airplane "...almost noiselessly." Several cockpit instruments and the on-board radar equipment were damaged and two holes in the fuselage were discovered upon landing.

⁵ This probably refers to Betty and Barney Hill who alleged having had a close encounter with a UA (Clark, Pp. 235-253, 1996; Fuller, 1966).

1992. "I was on a flight between Hawaiian islands during a very severe tropical storm in 1992. I was seated right beside the wing and was watching out the window when I saw a ball of "fire", whiteish in colour and bit smaller than a soccer ball hit the wing of the plane and bounce away toward the back of the plane in about a 90 degree angle. The plane's wing was seemingly undamaged by this and it did not enter into the metal and dissipate as I thought lightning would. I have always believed this was ball lightning that I witnessed, but did not know much about it at the time. What else could it be? Needless to say, I was a bit worried about my safety during the flight after seeing that."

Submitted: July 17, 2006 at 14:28:12 (PDT) <<http://amasci.com/weird/unusual/bl.html>>

No Date. "I am a 34 year retired flight attendant from delta airlines. Years ago I saw a 30 inch by 30 inch ball of multicolored lightening start at the front of the aircraft and roll, float, all the way down the aisle and straight through me as I sat on the center back jump seat. I was telling my family and they said that was very rare. There is no doubt that this occurred. I was not hurt in any way. I cant (sic) remember if we were in an electrical storm or not. Since I read that some doubt these things I just thought I would share this experience."

Submitted: May 30, 2006 at 22:00:18 (PDT) <<http://amasci.com/weird/unusual/bl.html>>

No Date. "One (TU134) pilot reported that at an altitude of 10,000 ft. and flying at a velocity of 800 km/hr (~220 m/s), the ball (in this case green) "appeared as though tethered behind the aircraft." (Anon, Pg. 2-9, 2000)

Our chief concern here is to determined whether BL might account for any of the pilot reports of UAP that are presented in sections 3.1, 3.2, and 3.3 of this report and not necessarily to show that BL is a danger to aviation (although this is an important topic and has been addressed elsewhere) (Anon, 2000, Rakov and Uman, 2003; Singer, 1971). Our intent is to try to show whether BL might account for the UAP pilot and ground witness reports presented previously. To accomplish this it is necessary to compile a list of physical and perceptual attributes of BL from the literature against which these pilot and ground witness descriptions may be compared. As shown in Table 1, the list of primary characteristics of BL vary widely.

Table 1

Reported Characteristics of Ball Lightning*

Appearance onset: gradual, suddenly (70% appear during or soon after a lightning strike)
Disappearance (decay): gradually, suddenly, explosively (with or without producing damage)
Color ⁶ : White, blue-white, yellow-white, red, orange, green, blue, violet
Luminosity: very dim to blindingly bright (most equivalent to a low-to-medium wattage tungsten lamp, none were black)
Surface Luminosity: uniformly bright (76%) ⁷
Constancy: remain relatively constant in luminance and size over their "lifetime"

⁶ Soviet research (Smirnov, 1987) on a database of 4,112 reports reported that 80% of them were accounted for by white, red/pink, orange, or yellow self-luminous balls.

Sparks/ashes/beams: rare but some reports exist⁷
 Heat: rarely experienced in close proximity
 Electrical Charge: none, significant (estimates range from 1,000 to 2,000,000 Joules)⁸
 Tail: none, comet-like, flames
 Halo: rare but some reports do exist
 Opacity: transparent, translucent, opaque
 Size: < 1cm diameter to 1 m. [one reliable sighting >100 m diameter⁹]
 Shape: typically spherical (87% round)⁷ but with many variations (oval, cylindrical, ring, tear-drop)
 Motion: none, linear, zig-zag (rare), smooth curves, undulating wave, turn sharp corners, constant velocity, bounce
 Maximum velocity: 2+ m/sec.
 Rotation or spin: many described as spinning or vibrating (36%)⁷
 Direction of Motion: Horizontal (54%); Vertical (19%)¹⁰; almost all others have been reported
 Apparent Point of Origin: in thunder cloud, lightning strike impact point, mid-air
 Duration: from seconds to minutes with most lasting under 5 seconds¹¹
 Noises: none, popping, hissing
 Odors: none, ozone, burning sulfur, nitrogen (nitric) oxide,
 Others: can pass through glass, attracted to electrical conductor(s), independent of wind or air turbulence, pass through narrow cracks and reform on other side in original shape, burn holes through brick walls, does not discharge on touching a conductor to ground,

* Until such time as this phenomenon has been finally verified as possessing all of these characteristics, using thorough scientific procedures, they must be considered as only tentative.

British Ministry of Defense Research

A declassified report prepared by the DIS Scientific and Technical Group, UK on Ball and Bead Lightning (Anon, 2000) contains two sections relevant to this discussion. The first is titled "*Effects on Equipment.*" It states, "Apart from the reported 'static' on receiving equipment ... example effects (of ball lightning) are: Attachment to power lines/electrical wires/pylons (but no effect on the system reported); Entry of 'balls' of various diameters into aircraft cabins; Stopped (Russian) aircraft engine (1956); Military fighter destroyed (1948); Moved ahead of

⁷ Could the spherical phenomenon reported by the Brazilian commercial pilot in case 3 of 3.2.2 have been BL? Its very long duration during which it appeared to close on the airplane and the clear air conditions that existed at the time would argue against this explanation.

⁸ See section 7 of <www.ncas.org/condon/text/s6chap07.htm#s7>

⁹ Abrahamson, J. et al., (Ed.), *Philosophical Transactions of the Royal Society of London*, Series A, vol. 360, Pp.22-23, 2002. Note: This very large self-luminous phenomenon was not a ball seen in the air but at ground level with an estimated width of 100m and height of 200m in a "fan shape." It lasted only about seven minutes and changed from a deep red to orange-yellow to white with a red halo.

¹⁰ Rayle, W.D., *Ball Lightning Characteristics*, NASA TN D-3188, Pg. 13, 1966.

¹¹ One source cited a BL in Japan that allegedly remained for 2 hours and was 6 m in diameter <www.bprc.mps.ohio-state.edu/~bdaye/balligh.html> Of course, whether it really was BL or not was never verified.

aircraft (Russian 1956); Russia (1959) caused 100 deg compass error. The aircraft incidents above were at altitudes from 2500m to 3400m. Some general EM effects on equipment (not necessarily ball lightning are also discussed at Working Paper No. 1 Annex D)."

The second section of some interest in this report from the UK is titled "*Ball Lightning and Aircraft*." (Selected portions are included here); for example, "41. The reported incidences of ball lightning 'flying' ahead or behind aircraft have brought about some investigations into the expected characteristics of ball in the aircraft airstream. It seems likely that the incidence of sightings of 'foo fighters' (as they became known in World War 2) would increase, purely because of the huge numbers of aircraft flying - certainly much more night flying than had been carried out in the short history of manned flight."¹²

"42. It is stated that large radius ball lightning (similar plasma bodies) can 'chase' aircraft while maintaining shape and more or less constant distance from the aircraft. The 'ball' is able to do so because it is not solid (otherwise a thrust force of thousands of Kg would be needed)! It is postulated that the layer of air adjacent to the surface of the ball loses its viscous properties. The ball follows the aircraft even in manoeuvres. Observations of ball lightning show that its characteristics do not change appreciably during its lifetime. When it is in the airstream of an aircraft it is postulated that it behaves as a non-deformable solid sphere in the airflow which holds its position due to the electrical/magnetic charges, described elsewhere in the Working paper.¹³ The main reason for interest in close encounters of aircraft with ball lightning is one of flight safety. It is reported that large balls can be comparable with body diameter of large aircraft and can be 'captured' by the exhaust from engines and 'chase' the aircraft at a velocity of 150-200m.s (278-370 kts), maintaining an apparent constant range from the tail assembly."

Because the USSR considered ball lightning as "very important," Gaidukov (1993) modeled these interactions and made specific suggestions on how pilots should cope with thunderstorms in general and ball lightning in particular. Several of his recommendations are relevant here:

"All efforts should be made to avoid lightning seen ahead (before a ball is formed)"

"...pilots should circle (fly) around a vertical line passing through the center of the lightning"

"...every effort should be made to place the ball astern, where it will assume a stable position"

"The balls cannot 'catch up' (with) the aircraft once the pilot has ensured that the ball is astern."

The author of the classified UK report commented on Gaidukov's suggestions: "The instances of phenomena of ball lightning ahead of or behind aircraft is relatively rare, but the Russian research suggests, apart from initial lightning avoidance, that the aircraft would be safe with the ball astern," "Reports of balls above aircraft 'pushing or forcing' an aircraft to

¹² A study of pilot reports of phenomenon described as ball lightning (conducted by the author) does not show a concomitant increase in the number of sighting reports commensurate with the increased number of airplanes flying over the years.

¹³ Also see 2.1, 2.2, and 2.3 in this regard.

descend are of concern, even if the ball does not cause physical damage its presence is clearly menacing to the uninitiated - especially as it occurs suddenly," "A 'collision' from astern is not considered likely," "A 'collision' head-on is possible and its imminence might cause violent pilot (control) reaction even though the contact may not (at the last moment) have actually occurred." (Anon, Pg. 2-9, 2000).

It is interesting to note that in their summary of this U.K. study of Ball and Bead Lightning the statement is made, "... it (ball or bead lightning) is certainly connected with a proportion of the UAP reports received from within the UK airspace. Descriptions of these particular forms of lightning correlate in time, colour and motion with qualitative description often given¹⁴ by reliable UAP witnesses." (Ibid., pg. 2-12) This report was apparently a part of (or linked to) a larger study of UAP as well as being oriented toward flight safety. Also, this kind of conclusion begs the questions whether the MoD wasn't trying to explain away at least some of their UAP sightings as BL. One might ask how did they unambiguously discriminate one phenomenon from the other in order to come to this rather grand and sweeping generalization that "a proportion" of UAP were actually BL? To do so implies that the MoD knows their essential differences.

Comparison of BL and UAP Reported by Pilots and Others

While a strong supportive case can be made that an individual pilot sighting report was caused either by BL or a UAP because it "fits" most of the distinctive characteristics of either phenomenon this does not prove that all UAP actually are BL nor does it prove the opposite. When pilot sighting reports contain sufficient supporting data and are carefully analyzed it becomes clearer than the two phenomenon are indeed different from one another in several ways. Here we shall consider three of them: appearance, motion (behavior), and duration of so-called UAP. For the sake of discussion we will make the still unproven assertion that they are different phenomenon.

Appearance: Do most UAP look any different from BL or put another way, are the appearances of each one so different that they do not overlap in their visual characteristics at all? Of course, the obvious answer must be yes and no, depending on the particular data that is being analyzed. In Section IX of his review of sightings over the thirty year period of 1964 to 1994 Hall (2001) shows how diverse the appearance of UAP (he calls them UFO) are; he covers structure (i.e., shape), lights, and colors. Elsewhere in this report (5.2) the author has reviewed a number of other investigators' work to find out what percentage of the total sightings were represented by each shape. Table 2 summarizes the key points from this review to illustrate the relatively high percentage of spheres that were reported.

¹⁴ Does this statement mean that simultaneous, independent reports generated both by reliable eye witnesses and scientific equipment of the same BL phenomenon in locale, color, motion, and time have been documented?

Table 2

Summary of Shapes from Several Researches
(From 5.2 in the present report)

Reference/Source	No. Diff. Shape Names or categories	Percentage of all Shapes that were "Spheres"	Number of Cases	Comments
USAF, Blue Book, Report 14.	7	0	498	Either the air force never received any reports of spheres or they deliberately re-named them to fit into another category
Vallee (1969)	7	24	433	
Shepard (1969)	33	8.7	206	"Sphere" and "Ball" combined. If "circular" and "round" are added the total is 26%
Gindilis et al. (1979)	7 (main categories) 20 (all shape names)	11 11 ¹⁵	256	"Regular sphere" and "Deformed sphere" combined.
Hall (2001)	5	0	67	No "spheres" were cited.
Weinstein (2009)	26	11.8	205	Combined "sphere," "balloon," and "globe"

When one stands some distance back from the large number of pilot sighting report details of unidentified aerial phenomena one discovers a certain consistency of their appearances.

In order to carry out a comprehensive comparison of UAP and BL visual features it would require an enormous amount of time and resources.¹⁶ Nevertheless, we have noticed that a relatively large percentage of UAP are described as large, reflecting or self-luminous, solid (or at least rigid) objects (spheres in the present case) that are on the order of several m or more in

¹⁵ Duplication of reports "allowed for" (i.e., included here).

¹⁶ The interested reader should consult these references for more detailed information: (Haines, 1980; Hall, 1964, 2001)

diameter). It may be pointed out from Rayle's survey data that the estimated diameters of BL range in the 1 to 35 inch range with a few somewhat larger.¹⁷

It is understandable that there are so few accurate measurements either of BL or UAP because humans are notoriously error-prone in making this judgement for many reasons (Haines, 1980). Nevertheless, there are enough pilot reports of extremely large spherical UAP that are (later) shown not to be balloons to suggest that they are not BL.

Motion (Behavior): As Singer (1971) has documented, a phenomenon called BL or "fireballs" have appeared near airplanes in flight and some have entered the interior, often by passing directly through the cockpit windshield!¹⁸ There are no reported instances of UAP doing this, usually because of their enormous size as discussed above. Also, some UAP are described as performing complete and even repetitive loops around an airplane in the vertical plane and others in a horizontal plane. If BL is the cause of these reports one must explain how it carries out such complex trajectories. The hypothesis that BL follows an ionized pathway near an airplane fails in this regard. Finally, some UAP are described as coming to a complete stop in the air while the airplane continues flying away; the phenomenon then accelerates at a high rate to catch up with the airplane and then slow to its exact forward velocity for a time before departing or disappearing. Again, proponents of this hypothesis must explain how it occurs.

Even a cursory review of the serious literature describing UAP shows that some can attain velocities many times the speed of sound as well as extremely high accelerations. BL, on the other hand, are very seldom described in these terms.

Gaidukov (1993) recommended two things for pilots to do if they should encounter BL: (1) "...every effort should be made to place the ball astern, where it will assume a stable position," and (2) "... the balls cannot 'catch up' (with) the aircraft once the pilot has ensured that the ball is astern." If these recommendations are accurate for BL then UAP are something quite different (3.1; 3.2.2).

Duration: As shown in Table 3, pilots in flight see UAP over a wide range of durations as might be expected. Nevertheless, with a grand mean duration of more than eleven minutes this translates to many miles of sustained travel beside (or in the vicinity) of the airplane. Whether BL can achieve this is open to serious question based on current knowledge of this ubiquitous phenomenon.

¹⁷ Shough (see Figure 4 in 2.3) has graphically summarized the estimated diameters of BL from data in Rayle (1966).

¹⁸ Modern airplane windshields are made of multiple bonded panes of thick plano-glass with extremely strong frames. They may be overcoated with certain deposited filters to reduce solar radiation transmission.

Table 3

Summary of Pilot UAP Sighting
Durations (min.)

Reference	Mean	Minimum	Maximum	Notes
Haines (1979)	8.5	seconds	75	Historical period 1973 - 1978, 69 separate cases (72 reports), two or more witnesses per case.
Haines (1983)	7.3	1 min.	84	Historical period 1942 to 1952, 283 cases, worldwide aviation.
Haines (1992)	17.5	seconds	180	Historical period 1945 to 1990, 56 cases only involving electro-magnetic effects on airplane.
Grand Mean 11.1 ¹⁹				

In his examination of ground witness reports of spherical UAP seen chasing airplanes and vice versa Lee (3.3.1) found durations ranging from seconds to ninety minutes! Given the accepted durations of most BL incidents (between seconds and several minutes), these long durations would make BL a less likely candidate to explain these reports than some exotic human technology. (e.g., see 4.2) or other explanation. Those who would continue to support the BL hypothesis for UAP sightings must explain how such long durations can be maintained.

Earthlights

Perhaps earthlights (EL) are some kind of physical counterpart of ball lightning. Like BL, EL have generated a plethora of explanatory hypotheses over the years yet there is little agreement on any one so far; happily we now see the activity of several highly qualified teams of investigators willing to actively study them in the field. The work of Strand, Teodorani, and co-workers is particularly noteworthy (2.4).

As Devereux and co-authors (pg. 165, 1989) has put it in regard to earthlights, "It seems that a delicate balance of conditions have to come together for lights to appear. Perhaps materials in the Earth's crust undergo temporary change due to pressure or other stimuli, allow the transient formation of superconductors, for example. The matrix that encompasses all of

¹⁹ For an airplane travelling at 150 mph, a period of 11.1 minutes corresponds to more than 27 miles of travel in straight and level flight (neglecting winds). Of course larger commercial jets travel considerably faster (and thus farther) than this. Such lengthy periods of observation make it possible for the eye witnesses on the airplane to make reasonably careful observations of the phenomenon.

the supporting conditions for earth light appearances is certain to be both large and complex, and it will take a long time to tease out all the factors that may be involved; some of these may have interchangeable roles and not always be present at any given occurrence of light phenomena."

It would seem that EL do not generally pose a threat to flight safety because of their low altitude and short duration. However, if they should occur at or near a runway at night the situation could change quickly.

Summary

The present abbreviated review of the reported characteristics of ball lightning do not correlate particularly well with the reported visual (and other) characteristics of UAP whatever they may be. On the balance the two appear to be separate phenomenon. Singer's (1971) list of potential hazards of BL to airplanes remains: "...explosions, temperatures high enough to melt metals, strong electrical effects, and force sufficient to deflect the craft from its path." Surely, ongoing research will alter this list.

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