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"Current Comments"

When Citation Analysis Strikes Ball Lightning

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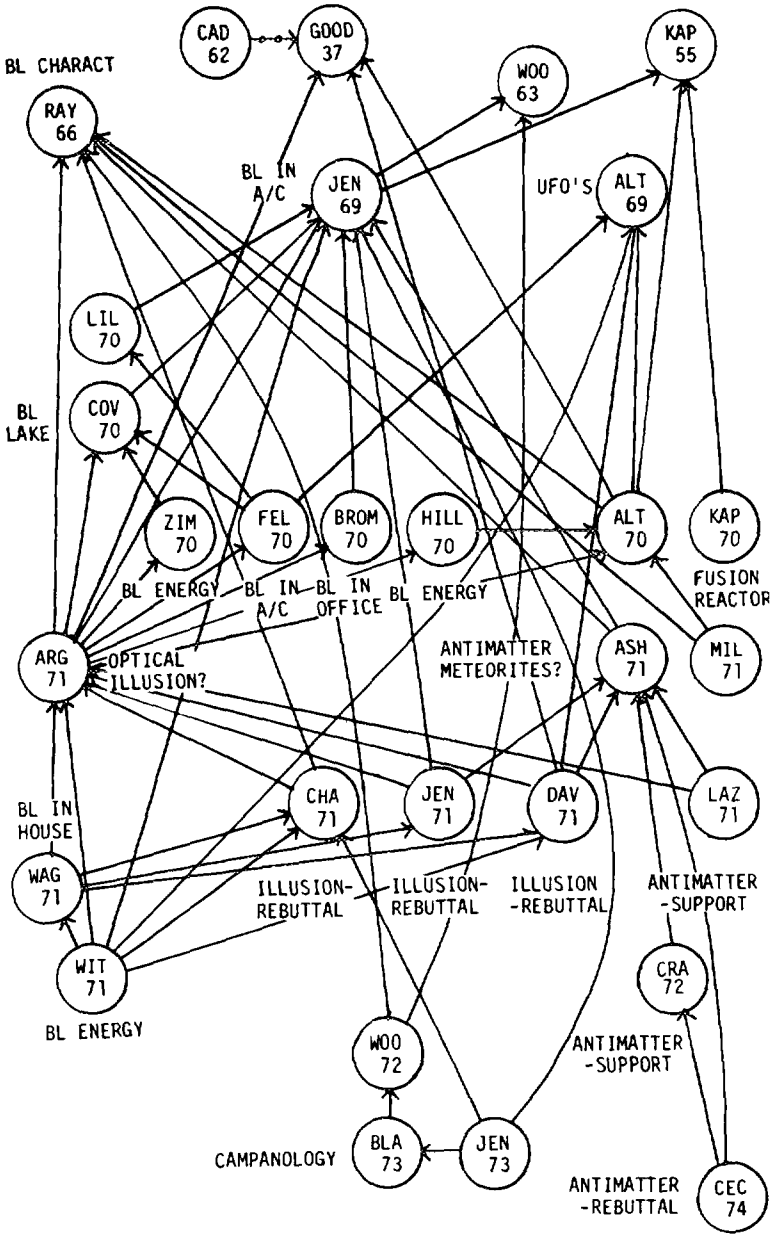
Thunder is good, thunder is impressive; but it is lightning that does the work.--Mark Twain[1]

Lightning has always terrified and fascinated people. It has also inspired many myths and much superstition. For example, some misinformed people righteously assert that lightning never strikes twice in the same place. Actually, the odds for lightning hitting twice in the same spot are excellent. The conditions that attracted it in the first place--a prominence in a flat area, for example--are likely to attract it again.

The Greeks and Romans thought thunderbolts were weapons of the gods. Since scientists have now explained ordinary streak lightning as a high-voltage electrical discharge, people's fascination has been transferred to the other forms of lightning: sheet lightning, in which no single bolt is visible; St. Elmo's fire, a glow emitted by charged objects such as airplane wings; and ball lightning (also called "Kugelblitz"). Ball lightning is usually described as a moving, luminous sphere which lasts a few seconds and then dies out, either silently or explosively. Ball lightning is probably the most mysterious lightning phenomenon because scientists have utterly failed to explain it. Many researchers have viewed reports of ball lightning with the kind of skepticism and distaste usually reserved for reports of psi phenomena and UFOs. Until recently, scientists even debated the existence of ball lightning--explaining it as hallucination, optical illusion, or observer hysteria. The only evidence for it was anecdotal, mainly from amateur sightings.

But reports of ball lightning have appeared in the scientific press for over a century. In 1885, *Science* published this account by a ship's captain named Waters: "All at once a large mass of fire appeared over the vessel, completely blinding the spectators; and, as it fell into the sea some fifty yards to leeward, it caused a hissing sound, which was heard above the blast, and made the vessel quiver from stem to stern."[2] In 1930, an anonymous account in *Nature* reported that "a number of globes of light were seen of the size of billiard balls, extending from a few inches above the surface to a height of 7-8 feet. They slowly rose and fell



"BALL-LIGHTNING" CITATION MAP

Articles are shown as circles containing author and year.
Adjacent words describe main theme of articles.

vertically, sometimes within a few inches of the observers but always eluding the grasp."[3]

It is always pleasant for me to demonstrate the creative use of information retrieval. The ball lightning phenomenon, with its combination of mystery and possible utility, is just such an opportunity. I hope that the new generation of science teachers will use the information retrieval techniques described here to get students interested in tracing the history of other scientific discoveries. By using the *Science Citation Index®* in this way, students can feel the excitement of discovery as the threads of scientific cloth are unraveled.

According to the results of a search by my versatile colleague, A.E. Cawkell,[4] an article with the incredible title "Thunderbolts as the X-Weapon" appeared in November 1962 in the now defunct journal *Discovery*. The paper, by C.M. Cade, contained this account of an attempt to calculate the energy of ball lightning: "A fireball 'the size of a large orange' which was observed in Dorstone, Hereford, on October 3rd, 1936, fell into a water butt containing about four gallons of water, which boiled for some minutes, and 20 minutes later was still too hot for the human hand. From this data, Professor B.L. Goodlet has calculated that the minimum energy of this fireball was 3,800 kilowatt-seconds...."[5] Unfortunately, the author supplies no further reference for the mysterious Professor Goodlet. So the detective work begins.

As it turns out, we were unable to find anyone who had ever cited Cade's paper, at least within the 15 years we've compiled the *SCI®* . But as I've often repeated, a name may be all one needs to begin an *SCI* search. Goodlet's papers in the *J IEE* were cited in 1970 by M.D. Altschuler of the National Center for Atmospheric Research, Boulder, Colorado; in 1971 by E. Argyle of the Dominion Radio Astrophysical Observatory, British Columbia; and again in 1971 by P.C.W. Davies of the Institute of Theoretical Astronomy, Cambridge, England. This is shown in the figure opposite, in which we have provided a selected portion of the now extensive ball lightning literature.

In 1971, Argyle drew parallels between ball lightning and visual afterimages: "The behavior and apparent properties of the positive afterimage are strikingly similar to those of ball lightning. Its shape will be the same as that of the exciting source, and it will commonly be described as a ball.... Positive afterimages last 2-10 seconds, depending on circumstances, and most lightning balls are reported to have a duration in the same range. Positive afterimages disappear rather suddenly, as do lightning balls."[6] Argyle dismissed Goodlet's report that water in a rain barrel had been heated by ball lightning as "unreliable."

Each explanation advanced for the ball lightning phenomenon is unsatisfactory in some respect. Early explanations held that ball lightning is formed by the combustion of material released by a lightning stroke on its impact with the ground. This material, either particles or gases, might be confined by a vortex, in the same manner as a smoke ring. Edward Hill of the University of Minnesota modified this theory to suggest that when a lightning stroke produces a separation of charges in such a ball of material, miniature lightning strokes occur within the ball.[7] T. Neugebauer postulated that ball lightning consists

of dense plasma containing large numbers of free electrons and positive ions.[8] Altschuler and his colleagues suggested that ball lightning may be a nuclear phenomenon involving the production of radioactive products, whose beta-decay would cause a glow in surrounding air molecules.[9]

A bizarre but not implausible theory was discussed in the same 19 March 1971 issue of *Nature* in which Argyle's "optical illusion" article was published. An article by D.E.T.F. Ashby and C. Whitehead of the United Kingdom Atomic Energy Authority suggested that ball lightning is caused by antimatter meteorites which annhilate normal matter, creating a luminous ball.[10] Actually, this idea was first proposed by Altschuler, who wrote in 1969 that "the hypothesis of antimatter meteorites is intriguing. If a significant amount of antimatter does exist in the universe, it is possible that tiny grains of antimatter might penetrate our galaxy and collide with the earth's atmosphere. Entering at high speeds, the grain might survive until it reached the troposphere. A fraction of a microgram of antimatter would destroy an equal mass of matter and release many megajoules of energy, perhaps creating luminous spheres."[11] The antimatter theory was supported when Ashby and Whitehead, using radiation detectors, observed four "unusual" radiation events. They concluded that, "The radiation events are consistent with the proposed existence of micron-sized particles of antimatter and their duration is similar to that of ball lightning; however, the correlation with thunderstorms is uncertain."[10]

As the ball lightning phenomenon became more scientifically respectable, two particular "events" began to be discussed by many authors. The first was Jennison's (University of Kent) 1969 report of a lightning ball passing down the central aisle of an aircraft. Since the plane was a tanker with a full load of aviation fuel, one can imagine the observer's relief when the yellow-white lightning ball "danced out over the right wing" and disappeared into the night.[12] The second event was Covington's (National Research Council of Canada) 1970 observations of a drifting lightning ball which demolished the pile of a wharf, and of another lightning ball which emerged from the fireplace in a lakeside house, traveled across the room, and passed through a closed door without causing any damage.[13]

The two articles by Argyle and Ashby were cited in several letters to journals in 1971. Argyle's idea that ball lightning is an optical illusion was rebutted by authors who cited their own and other observers' well-documented sightings. Ashby's antimatter notion had a mixed reception.

The UFO phenomenon entered the ball lightning story via Altschuler's 1969 article in the Condon UFO report, which explained some UFO sightings as ball lightning.[11] The chapter was cited by several authors.

As an exercise in demonstrating that all phenomena and disciplines are somehow connected to one another, the ball lightning story has few equals. In 1973, for example, A.J.P. Blair of Germany used a novel method to calculate the magnetic energy in a lightning ball as 150 gauss. *Nature* carried the report, which stated, "In the parish of Samford-Courtney in Devon on October 7, 1811, a sudden darkness came on, and a fire ball fell in the vicinity of the church. The ringers in the belfry, ringing at the time, declared that they never knew the

bells go so heavy, and were obliged to desist ringing. Looking down from the belfry into the church, they perceived four fire balls, which suddenly burst, and the church was filled with fire and smoke, some of which ascended to the tower, where a large beam, on which one of the bells was hung, was broken, and the gudgeon breaking, the bell fell to the floor."[14]

There is also a connection to nuclear fusion in the ball lightning story. In a well-cited 1955 article,[15] the Russian physicist Peter Kapitsa proposed that ball lightning results from a standing wave system in the electromagnetic field which accompanies thunderstorms. Windows and chimneys, through which ball lightning is often reported to have travelled, would act as waveguides for these standing waves. Elements of this idea were later used in a Soviet experimental fusion reactor, and stable balls of plasma were produced.[16]

Another theory involves focused cosmic-ray particles, and still another postulates that ball lightning is produced by the decay of ordinary lightning in the presence of large amounts of water.

The theoretical situation regarding ball lightning still is rather confused. It has not yet been determined whether ball lightning is a single phenomenon or a series of phenomena with diverse origins. No one has succeeded in producing ball lightning in the laboratory, although a few photographs have been reported.

Just a year ago, in a search for photographic evidence of ball lightning, two researchers at the University of Wyoming examined over 10,000 Prarie Meteorite Network photographs which contained images of over 100,000 lightning strokes. They reported finding six ball lightning "candidate" events. "In all of the ball candidate events the scenario is the same: an ordinary appearing lightning stroke ends above ground and what appears to be a ball (producing a sequence of images) falls out of it and goes to earth."[17]

More recently, photographic evidence of an object "which may be similar to some varieties of ball lightning" was reported in September 1975 by three French authors, R. Fieux and C. Gary of Electricité de France, Direction des Etudes et Recherches, and P. Hubert of Commissariat à l'Energie Atomique, Service d'Electronique Physique, Centre d'Etudes Nucléaires de Saclay.[18] In a kind of reenactment of Benjamin Franklin's kite-and-key lightning experiment, they launched rockets with wires attached into the atmosphere. This technique was developed, they said, "in the hope of perhaps shedding new light on the controversial subject of ball lightning, since according to published statistics ball lightning is mentioned in more than 40% of the cases in which an observer describes a nearby lightning stroke." Although these researchers did not observe anything "comparable with the more remarkable tales of ball lightning folklore," they did observe and photograph the appearance of luminous "beads" during the decay of triggered lightning. "The beads generally have an initial diameter of the order of 40 cm which decreases gradually with a total lifetime of 0.3s at most. During long-lasting strokes, the initially straight channel adopts on a progressively more tortuous shape and the biggest beads occur where tortuousness is a maximum. Since there is a positive correlation between diameter and lifetime, it follows that at the end of the decay there are one

The death of professor G. W. Richmann of St. Petersburg in 1753 has been ascribed to the first experiment which succeeded--accidentally--in producing artificial ball lightning. According to Stanley Singer,[23] as Richmann observed the effect of a thunderstorm on a device for measuring atmospheric electricity, lightning struck a rod connected to his apparatus, causing a lightning ball to travel from the device to Richmann's forehead. The fatal experiment was witnessed by a friend of Richmann, an engraver of the Royal Academy of St. Petersburg.

or two luminous balls only. In general these objects have an upward motion of 1 or 2 m s^{-1}, which gives an overall picture consistent with the hypothesis of a gradually cooling spheroid of hot gas."

In the same paper, the authors lend support to the early theory involving combustion of material released from the ground. They note that "light emission occurred at the foot of wooden posts" in the test area. "The light-emitting region was stationary, in contact with the ground at the place where the post enters the earth. Its shape seems roughly spherical with a diameter of about 25 cm...." They comment, "It is not surprising that some underground outgassing occurs and that the gasses escape at the point where the posts puncture the upper layer. It remains to be decided whether the light comes from hot gases only or from a combustion involving hydrogen or methane, for instance, or from a localized electric discharge mechanism."

Just a few weeks ago, Mark Stenhoff of the Physics Department of Royal Holloway College reported a case in which a woman touched and was injured by ball lightning. Stenhoff reported in *Nature* that on 8 August 1975, the woman, who lives in the Midlands area of England, was in her kitchen during a thunderstorm "when a sphere of light appeared over the cooker. The ball was $\sim$ 10 cm across and surrounded by a flame-colored halo; its color was bright blue to purple. The ball moved straight towards the witness at an estimated height of 95 cm from the ground. Burning heat was felt, and there was a singeing smell. A sound something like a rattle was heard."[19]

The woman herself reported that, "The ball seemed to hit me below the belt, as it were, and I automatically brushed it from me and it just disappeared. Where I brushed it away there appeared a redness and swelling on my left hand. It seemed as if my gold wedding ring was burning into my finger." The lightning ball produced a hole in the woman's dress and underwear at the point where it struck her. Her legs became red and numb. The woman, who had never before heard of ball lightning, felt that the ball exploded just as she touched it.

Commenting on this report in a *Nature* editorial, P.C.W. Davies notes that progress in ball lightning research is hampered by the lack of precise, reliable observational data. He suggests that, "The present unsatisfactory situation would be greatly improved if the aura of mystery and superstition surrounding unusual aerial events were dispelled. Good, detailed eye-witness reports of luminous balls are frequently made by competent observers such as airline pilots, but are rarely passed on to scientists. Instead, many of them find their way into military files, where they are shrouded in a ridiculous secrecy. (Incredibly, the British Ministry of Defence continues to deny scientists access to their accounts of these events.) With proper cooperation between scientists and the public, particularly the local press, and the civil aircraft authorities, it would be possible to follow up ball lightning reports rapidly, enabling tests for radioactivity and so forth to be carried out."[20]

To help clarify the situation, a few individuals have turned their energies to collecting ball lightning reports. One of these is William Corliss of Glen Arm, Maryland, a consultant to NASA who has compiled *Strange Phenomena*,[21] a "sourcebook" which

contains abstracts of 75 ball lightning reports. Also notable is the ball lightning bibliography compiled by J.D. Barry of the US Air Force's Space and Missile Systems Organization, Los Angeles. This bibliography, copies of which are available from the author, cites over 1,100 ball lightning reports and references spanning 350 years.[22] Another excellent source of information on the scientific history of ball lightning is a book published in 1971, *The Nature of Ball Lightning* by Stanley Singer, director of Athenex Research Associates, Pasadena, California.[23] According to Singer, Faraday felt that any relation between ball lightning and streak lightning was "more than doubtful," and Lord Kelvin held that ball lightning was nothing more than an optical illusion. The selected ball lightning bibliography which follows is intended to stimulate discussion, and possibly research, of this centuries-old but still fascinating subject.

Returning to the 1962 article by Cade, we've been unable to find any other articles about "X-Weapons." Maybe the idea was impractical--or maybe the work was so successful that it was classified. What surprises me most about the ball lightning story is the failure of any leading American or Soviet journal to present a comprehensive discussion of this area of research. The state of the literature on ball lightning is similar to Shakespeare's description of Romeo and Juliet's love:

It is too rash, too unadvis'd, too sudden;
Too like the lightning; which doth cease to be
Ere one can say it lightens.[24]

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