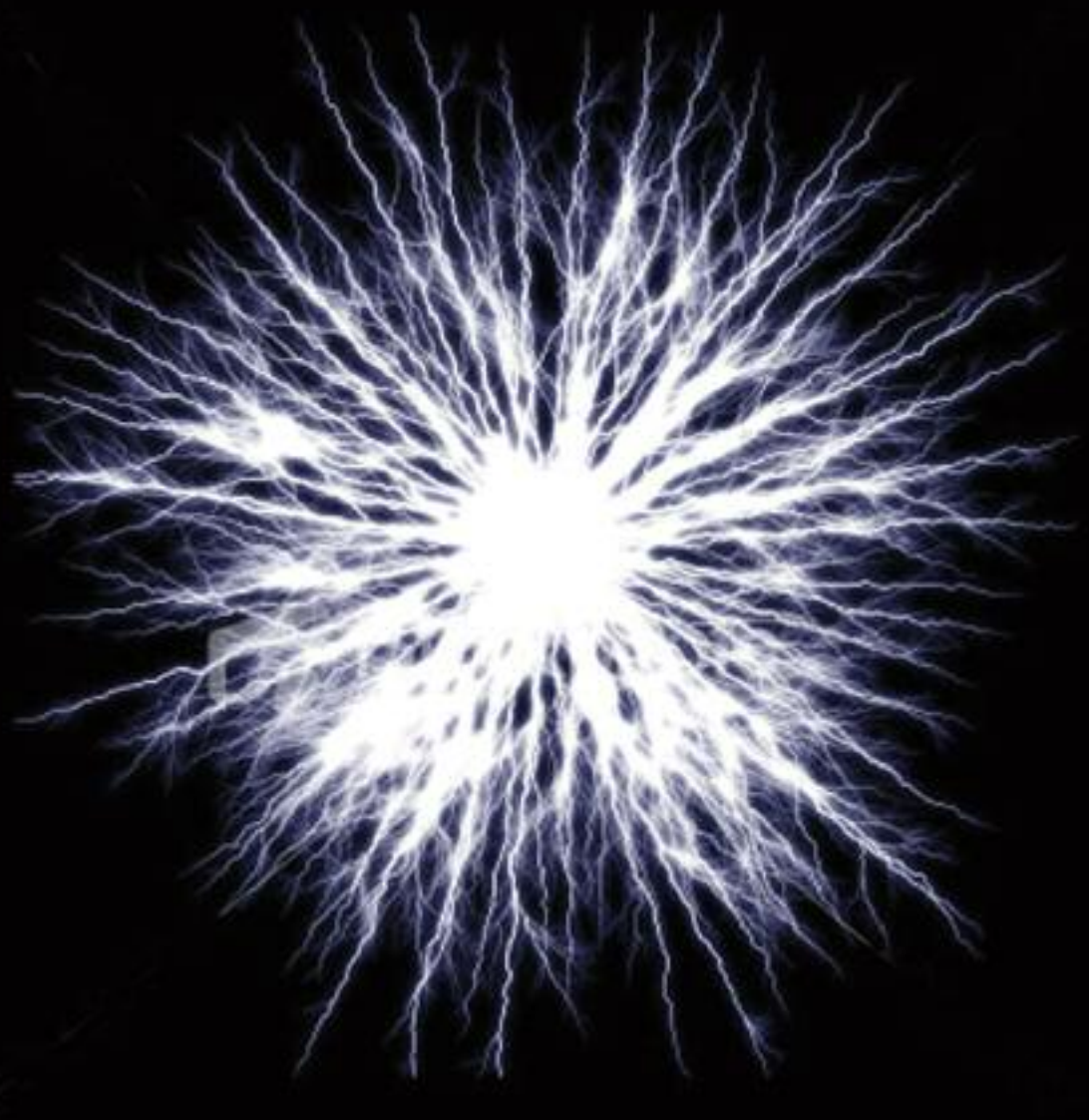
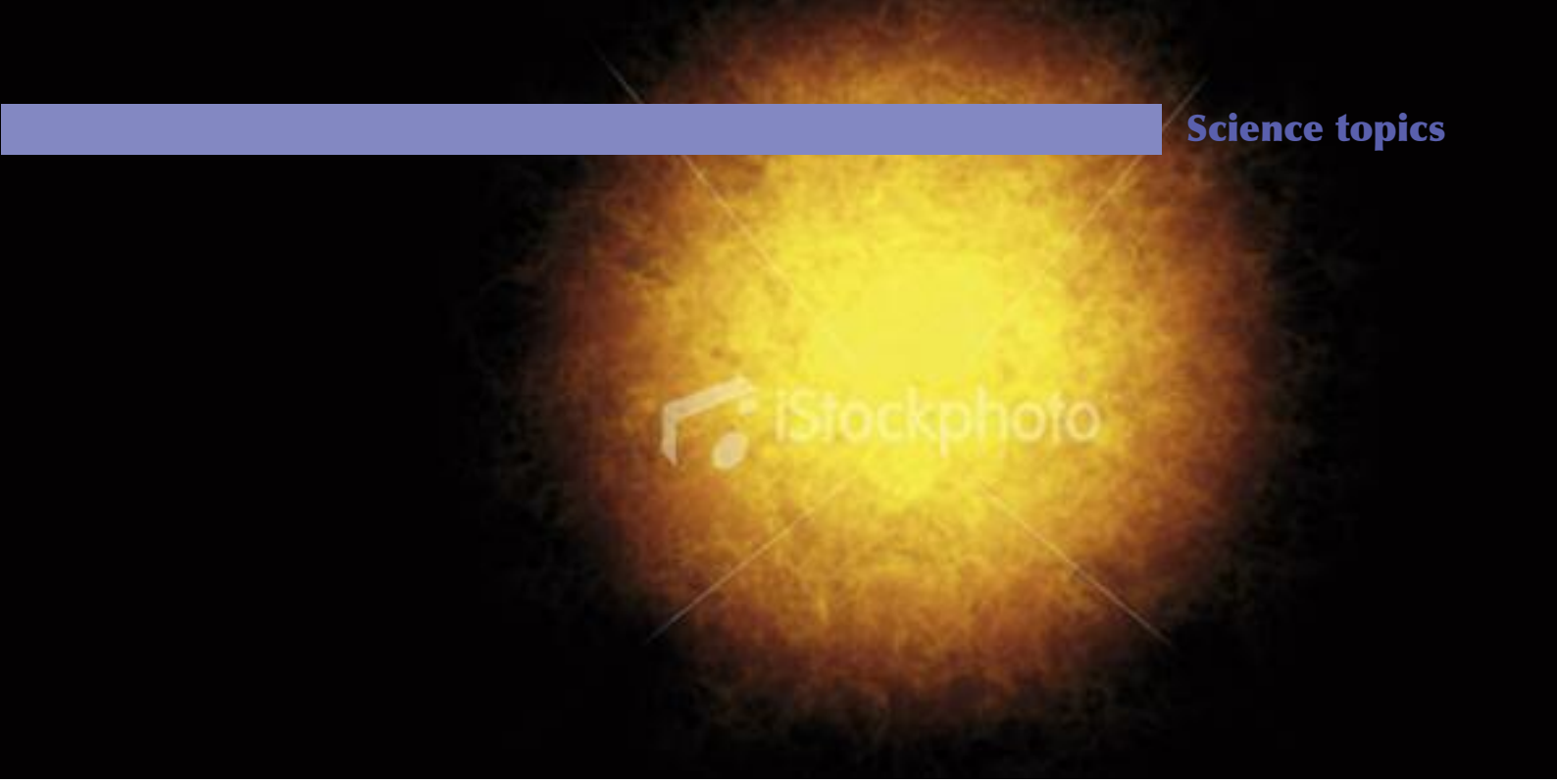


Ball lightning

Here, to accompany her article on creating plasma balls with microwaves and her microwave experiments for schools, **Halina Stanley** provides some supporting information



According to satellite surveys, there are around 1.4 billion lightning flashes worldwide a year on Earth, or about 44 a second (Christian *et al*, 2003), so we all experience thunder and lightning several times a year. Not many of us, however, have witnessed ball lightning. Those who have report glowing balls that may be red, orange, white, or even blue or green, the size of a tennis ball or as large as a melon. The ball lightning is usually, but not always, associated with thunderstorms and lightning. Balls tend to persist for several seconds, and may move horizontally or vertically. Some people say the balls can pass through windows without damage; others say they melt holes into objects.

Bychkov *et al* (2002) have collected several reports of ball lightning. One describes how a ball lightning disc touched the front steel part of a tram carriage, resulting in a smooth hole 50 mm in diameter and 1.5 mm thick. The ball must have had enough energy to heat the steel plate from room temperature to the boiling point of steel. In another report, a fireball fell into a trough of water, vaporising the water and cooking the frogs that were in the trough. In eight out of the seventeen reports, the ball lightning was not connected with ordinary lightning. On the Internet, there is a story in which a luminous ball left a hole the size of a basketball in a screen door as it entered a house in Oregon, USA, then navigated down to the basement and wrecked an old mangle. In another story, an 80 cm glowing blob bounced on a Russian teacher's head more than 20 times before vanishing[w1]. Ball lightning has appeared in an air force plane, and vanished without causing any damage. Clearly, ball lightning is a very strange phenomenon: it shines as brightly as a light bulb, does not radi-

Public domain image; National Oceanic and Atmospheric Administration / Department of Commerce

Ball lightning – 'Globe of fire descending into a room' from *The Aerial World* by Dr G. Hartwig, London, 1886.

BACKGROUND

Ball lightning in New York

I saw ball lightning during a thunderstorm in the summer of 1960. I was 16 years old. It was about 9 pm, very dark, and I was sitting with my girlfriend at a picnic table in a pavilion at a public park in upstate New York. The structure was open on three sides, and we were sitting with our backs to the closed side. It was raining quite hard. A whitish-yellowish ball, about the size of a tennis ball, appeared on our left, 30 yards away, and its appearance was not directly associated with a lightning strike. The wind was light. The ball was eight feet off the ground and drifting slowly towards the pavilion. As it entered, it dropped abruptly to the wet wood plank floor, passing within three feet of our heads on the way down. It skittered along the floor with a jerky motion, passed out of the structure on the right, rose to a height of six feet, drifted ten yards further, dropped to the ground and extinguished non-explosively.

As it passed my head, I felt no heat. Its acoustic emission I likened to that of a freshly struck match. As it skittered on the floor, it displayed elastic properties (a physicist would call them resonant vibrating modes). Its luminosity was such that it was not blinding. I estimate that it was like staring at a less than 10-watt bulb. The whole encounter lasted for about 15 seconds. I remember it vividly even today, as all eyewitnesses do, because it was so extraordinary. Not until ten years later, at a seminar on ball lightning, did I realise what I had witnessed.

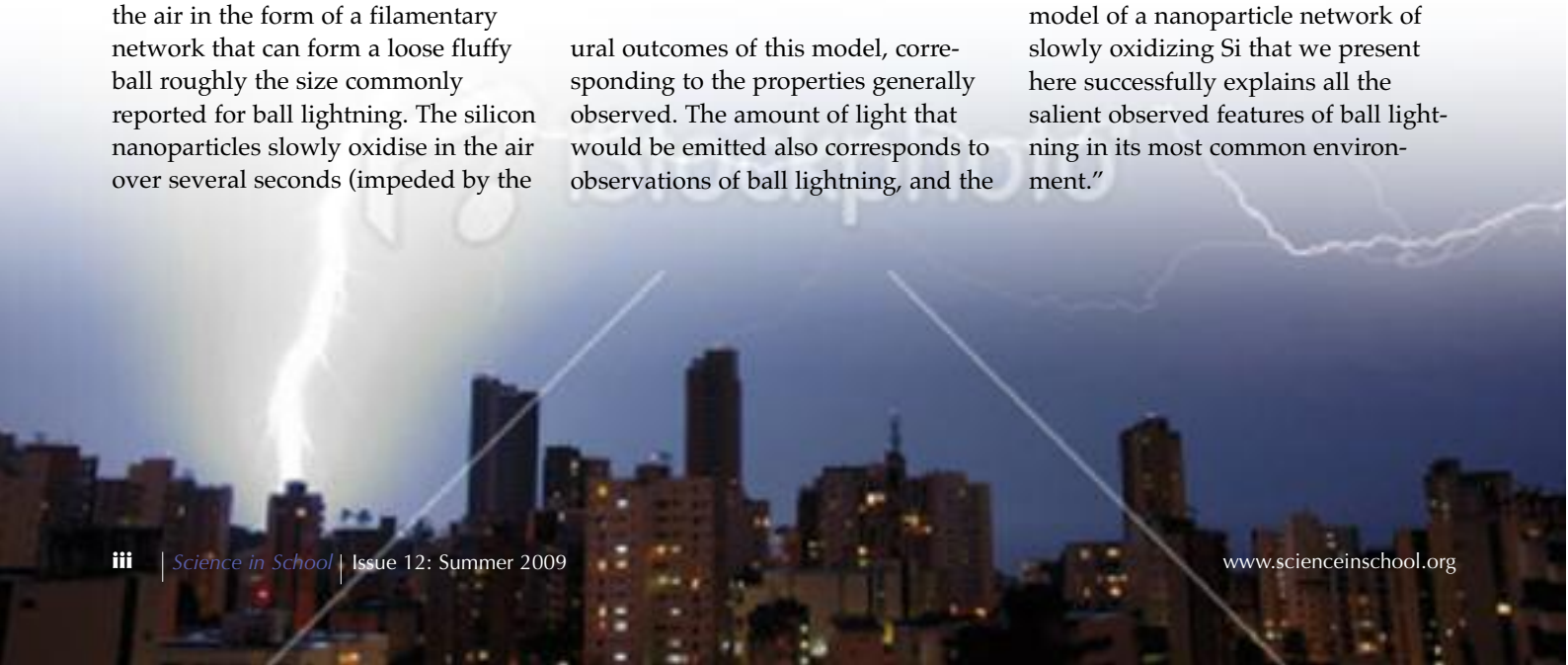
From Hubler *(2000)*

ate much heat, but can melt through steel and cook frogs. It is a rare and unpredictable event, and no one is at all sure what it is.

You can watch a video of what is supposedly ball lightning online[w3].

According to one model of ball lightning[w2] (Abrahamson & Dinniss, 2000), when ordinary lightning strikes the ground it can reduce silica in the soil to silicon. A cloud of very fine silicon, silicon carbide, silicon oxide and soot nanoparticles is then ejected into the air in the form of a filamentary network that can form a loose fluffy ball roughly the size commonly reported for ball lightning. The silicon nanoparticles slowly oxidise in the air over several seconds (impeded by the growing surface oxide layer), releasing heat and light. A cool outer surface and a lack of radiant heat are natural outcomes of this model, corresponding to the properties generally observed. The amount of light that would be emitted also corresponds to observations of ball lightning, and the differences in observed colours can be explained by different temperatures of the oxidising cluster (arising from different starting conditions) and the possible presence of various metallic ions from the soil. For lower starting temperatures, the ball may become visible only over the latter part of its lifetime, which could be after minutes, so that it is not easily connected with the formative lightning strike. Abrahamson and Dinniss conclude their paper with the statement: "The model of a nanoparticle network of slowly oxidizing Si that we present here successfully explains all the salient observed features of ball lightning in its most common environment."

> An 80 cm glowing blob bounced on a Russian teacher's head more than twenty times before vanishing



Questions for students

1. Do you think that Abrahamson's model successfully explains ball lightning? Why or why not?
2. Do you think plasma balls formed in a microwave oven (see Stanley, 2009) help explain ball lightning?
3. In what ways does ball lightning resemble the plasma balls formed in microwave ovens, and in what ways do they differ?

References

Abrahamson J, Dinniss J (2000) Ball lightning caused by oxidation of nanoparticle networks from normal lightning strikes on soil. *Nature* 403(6769): 519-21, doi:10.1038/35000525. Download the article free of charge from the *Science in School* website (www.scienceinschool.org/2009/issue12/fireballs), or subscribe to Nature today: www.nature.com/subscribe

Bychkov AV, Bychkov VL, Abrahamson J (2002) On the energy characteristics of ball lightning. *Philosophical Transactions of the Royal Society of London* A 360, 97-106. doi: 10.1098/rsta.2001.0922

Christian HJ *et al* (2003) Global frequency and distribution of lightning as observed from space by the optical transient detector. *Journal of Geophysical Research* 108(D1), 4005. doi: 10.1029/2002JD002347

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Stanley H (2009) Plasma balls: creating the 4th state of matter with microwaves. *Science in School* 12: x-y. www.scienceinschool.org/2009/issue12/fireballs

Web references

w1 – For the anecdote of the Russian teacher and ball lightning, see: www.newscientist.com/article/dn1720-ball-lightning-scientists-remain-in-the-dark.html

w2 – To read about the recreation of ball lightning in the lab, see: www.newscientist.com/article/mg19325863.500-lightning-balls-created-in-the-lab.html

w3 – You can watch a video of ball lightning here: http://commons.wikimedia.org/wiki/File:Mistifikatsia.gif

w4 – The Weird Science Page database of ball lightning reports can be found here: http://amasci.com/weird/unusual/bl.html

Resources

For Halina Stanley's collection of microwave experiments to perform at school, see:

Stanley H (2009) Microwave experiments at school. *Science in School* 12: x-y. www.scienceinschool.org/2009/issue12/microwaves

BACKGROUND

Ball lightning in Pennsylvania

Early this past summer (June 2006) as I sat at my computer answering e-mail (and considering shutting down the computer because a storm was brewing) something caught my attention to the left. As I looked toward my front door I saw a cantaloupe-sized orange ball of flame appear about three feet off the ground. It was about 15 feet away.

My cats, wide-eyed, were also watching the thing. Just as my brain sorted out what I was looking at, the orb pulled in on itself, turned a bright white, and snapped! The image was much like an old TV tube when turned off. The snap was louder than any electrical arc I've ever heard. My cats – upstairs and down – freaked out!

The whole thing lasted only about four to five seconds. I assumed our house had been hit by lightning, called my husband to let him know, and walked through (and later outside) the house to see if there was any damage. I found none.

Elizabeth Goss from Lancaster, Pennsylvania, USA, reported in the The Weird Science Page *database of ball lightning reports*[w4]