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BALL LIGHTNING: THE UNSOLVED PROBLEM

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IT is one of the pleasures of meteorology that many of its phenomena are still imperfectly understood. Few, however, remain such a complete enigma as ball lightning (BL), or Kugelblitz, the name give to the mobile, long-lived, luminous spheres which, for many centuries, have been occasionally reported in the vicinity of thunderstorms and elsewhere. The difficulty of accounting for the alleged properties of these balls, notably their relatively lengthy existence of several seconds, has led several prominent authorities, including Lord Kelvin a hundred years ago, to speculate that the witnesses have been mistaken in their subjective description of the events. In particular, it has often been proposed that what the observers are 'seeing' is, in fact merely the positive after-image of some short-lived initiating event, usually a conventional lightning discharge, and that this lingering retinal after-image, projected onto the real world, is then 'seen' as a ball (e.g. Humphreys 1936; Argyle 1971). Such a Draconian solution to the problem seems untenable, mainly because BL is often observed in the absence of any obvious triggering lightning flash, while after-images are known to undergo a sequence of temporal changes which find no parallel in ball lightning reports (Charman 1971a).

The aim of the present review is to summarise briefly the available eye-witness reports and related objective evidence and to point out the limitations of these data. Some theories for the origins of the balls will then be outlined, together with their successes and failures in accounting for the observations. Lastly suggestions for possible future studies will be made. In the preparation of this review much use has been made of the data compiled by earlier authors, notably Barry (1980), Charman (1978), McNally (1966), Rayle (1966) and Singer (1971; 1977). Barry's book contains an excellent, comprehensive and up-to-date bibliography.

EYE WITNESS EVIDENCE

Before sketching the general picture that emerges from the over 2000 reports that appear in the literature, it will be useful to give examples of typical reports; others have appeared in past issues of *Weather* (e.g. King 1972; Ord 1974; Colucci 1976; Hunt 1979). The second example below is similar to one described on p. 90.

> 'Round about 1943, when I was a boy of 13 years, I was in the kitchen of our house in Colney Lane just outside Norwich. The window of the scullery was open, and I noticed a round ball of about 5–6 cm in diameter, glowing with an orange colour, drift through it. It drifted through the scullery into the kitchen at a height of about 2½ m and hovered by the down wire of the electric light. It was too high for me to see properly, so since there was a chair near, I climbed on to it to take a closer look. As I was mounting the chair the ball went off with a loud pop, and disappeared.'
>
> J. N. STRETTON-DOWNES, 1972

> 'About fifty years ago I was standing on the steps of a shop in Orford Place, Norwich, sheltering from a violent thunderstorm. In front of me stood a tram – empty. Suddenly a large fireball descended – I did not see from where – but it was the size of a football. It passed through the rear apron of the tram, travelled the length of the tram inside and out through the front apron, and then exploded on the ground outside.
>
> After the storm had subsided I got down from the steps and examined the tram. There was a large hole in the rear apron and also in the front apron.'
>
> R. P. BURGESS, 1972

FEATURES OF BALL LIGHTNING

While any report has its own idiosyncracies, several features of these and other records deserve comment. First, most reports appear sober with reasonable circumstantial detail; they are often made by people who had no previous knowledge of BL. Damage or other after-effects suggest that some real physical event was observed. Details such as the climbing of the chair in the first example quoted lend credence to a timescale of several seconds for the event. Often more than one witness describes the event in similar terms. On the other hand, as in both the cases cited, the descriptions are often collected many years after the actual occurrence of the event and it may well be that memories of many details have become either distorted or lost. Other perceptual limitations which inevitably affect the accuracy of all descriptions, no matter how short the delay in recording, are discussed in detail elsewhere (Charman 1971b).

With these considerations in mind, a composite picture of a 'typical' BL event can be obtained.

Occurrence

Although in a majority (70 per cent) of cases the balls are reported at times of thunderstorm activity, this is by no means always the case and there is no obvious need for a conventional flash to have occurred before the observation of BL. Consideration of the distances over which ball and conventional lightning might be observed, perhaps of the order of tens of metres and kilometres respectively, allied to the apparent frequency of reports of the two phenomena, suggests that the true frequency of occurrence of ball lightning may be 10 per cent of that of conventional discharges (Rayle 1966). Thus BL may not be rare, although it will be difficult to observe because its small dimensions mean that it can only be detected if it is relatively close to the observer. There is no obvious correlation of events with the presence of dust, water or any particular form of terrain, in spite of suggestions by some theorists that these may favour ball formation. Many balls are observed inside buildings or even, remarkably, inside metal-skinned aircraft (e.g. Jennison 1969, 1971, 1973).

Size and shape

Most observers describe quasi-spherical objects, although annuli, cigar forms, pear shapes and other bizarre types have occasionally been noted (e.g. Corliss 1977). Fig. 1 plots the distributions of diameters in three collections of reports. While it should be remembered that essentially any observer starts by making an estimate of angular diameter and that his estimate of linear diameter therefore depends upon him next making a correct estimate of the distance of the object, there appears to be reasonable agreement that most balls have a diameter in the range 10 to 40 cm, with very few exceeding 1 m in diameter. Relatively few objects are described as undergoing marked changes in size during their lifetime.

Duration

Estimates of this important parameter are given in Fig. 2. While these are again subject to a variety of errors, circumstantial details, such as witnesses calling to other people to view the event, support a typical duration of several seconds. Circumstances may, of course, prevent the observer from seeing either the birth or death of the ball, leading to an under-estimate of the ball's life.

Colour and brightness

These are, perhaps, the least certain attributes of the balls, since the observers' descriptions are heavily dependent upon their state of visual adaptation. A ball which might be described as blindingly bright if observed at night would appear relatively dim if seen by day. Observations made where street or interior lights are available for comparison suggest that the balls may have a comparable luminance to these artificial sources. A wide variety of colours have been reported, with a preponderance at the red and yellow end of the spectrum. Accurate colour information might be suggestive of ball temperature or the presence of particular materials in the composition of the ball; again, however, perceptual limitations on the part of the observers make their reports of this parameter of limited value. Reports of noticeable thermal emission are relatively uncommon, in spite of the frequent description of the objects as 'fireballs'.

Movement

It is, of course, this property that sharply differentiates BL from discharge phenomena such as St Elmo's fire which remain firmly anchored to the discharging points. Most BL moves slowly at a few metres per second, the movement being somewhat faster in cases where the object falls vertically from the clouds. Although balls are occasionally described as moving against the wind, it remains possible that their motion is influenced by local air currents. Occasionally, too, the motion seems to be guided by features such as walls or fences but there is nothing to suggest that these are obviously associated with ball formation. In most cases the direction of motion is predominantly horizontal. Significantly, in view of theories ascribing the balls to hot gas, there are very few reports of an upward vertical motion. A substantial fraction of reports describe the object as 'spinning' or 'rolling'; other balls apparently 'bounce' when they come in contact with the ground or pass through narrow apertures.

Disappearance

Here a wide variety of behaviour is described. As already noted, regular shrinkage of the objects is comparatively rare and the actual disappearance may be silent or explosive, with varying degrees of violence ranging from a gentle 'pop' to a shattering roar. Damage effects occur in a minority of cases and these have been used to obtain estimates of the energy contained in the balls. The classic case, where a ball conveniently dived into a barrel of water, causing it to boil, has been used to estimate a corresponding ball energy content of 10^7 J (Goodlet 1937). In general, little remains after the ball has disappeared but occasionally a fine mist, a tarry residue or smells of ozone or oxides of nitrogen have been remarked upon.

OBJECTIVE EVIDENCE

It might be thought that photographic evidence would be of immense value in clarifying the characteristics of ball lightning. Unfortunately this is hardly true of available photographs, most of which were obtained more or less by chance by photographers seeking to record normal thunderstorm activity.

Two main types of photograph exist. In the first of these, the camera shutter is left open after dark during a thunderstorm for several seconds, in the hope that a normal short-lived discharge will occur and be faithfully recorded on the film. Under these circumstances, the track of any moving BL will appear as a complex, irregular streak. Regrettably, very similar effects can easily be produced during long time exposures with a fixed light source, for example a street lamp, and a moving camera. Much vigorous controversy about the authenticity of photographs of this type has therefore resulted, not least in the pages of *Weather* (e.g. Petersen 1954a & b; Dixon 1955; Poulter 1954a & b; Scott 1955). Moreover, not only does the validity of such photographs hinge upon the photographer's statement of the conditions at the time of the exposure but also, even if the photograph is accepted, interpretation of the trace in terms of ball dimensions and movement is only possible with the aid of supporting eye-witness testimony, as the photographic record is confined to two dimensions.

The other main class of photographs, fewer in number, records individual objects with short photographic exposures. Again, the two-dimensional nature of the photographic record means that any derived estimates of ball dimensions are dependent upon the availability of a distance estimate from eye witnesses and, interesting though these photographs are, it seems fair to say that they merely corroborate the eye witness descriptions and add little new information. An almost complete collection of published photographs of the two types can be found in Barry's recent book (Barry 1980).

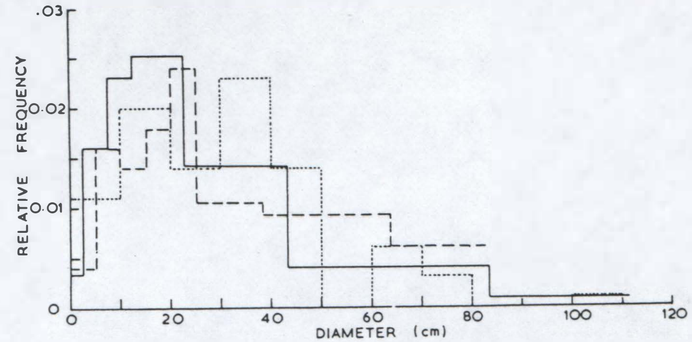

Fig. 1 Distribution of ball lightning diameter, according to three typical surveys.
——— McNally (1966), 446 events; — — — Rayle (1966), 98 events; .... Charman (1978), 64 events

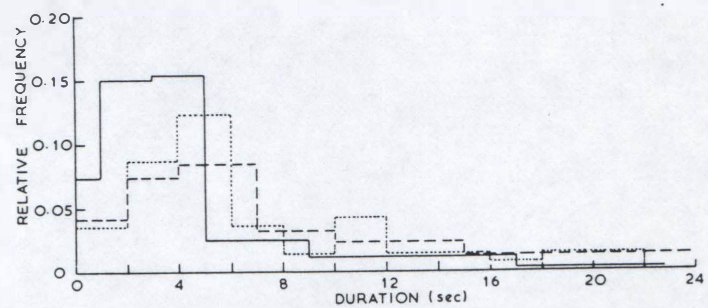

Fig. 2 Distribution of ball lightning durations, according to three typical surveys.
——— McNally (1966), 446 events; — — — Rayle (1966), 98 events; .... Charman (1978), 64 events

In addition to these 'chance' records, a limited number of images have been obtained during the course of systematic scientific studies. Particularly interesting, and apparently fruitful, has been the scrutiny by Tompkins and Rodney of some ten thousand photographs obtained with the cameras of the Prairie Meteorite Network which, as their name implies, were operated over several years in a programme to record the passage of meteors in the skies over some 10^6 km^2 of North America. Each camera was equipped with a shutter which interrupted the exposure 13⅓ times per second, the overall exposure lasting 4½ hours. Thus, whereas the slow apparent movement of stars caused by the rotation of the earth would leave effectively continuous traces on the film, a fast-moving meteor would generate a record consisting of a series of dashes. Additional coding breaks on the record allowed the time of the meteor's passage to be inferred. Even Prairie skies are not cloudless and Tompkins and Rodney realised that many photographs would record lightning events. As the actual exposure during each shutter-open period was only 25 ms, a normal short-lived

Photograph by courtesy of Dr D. R. Tompkins

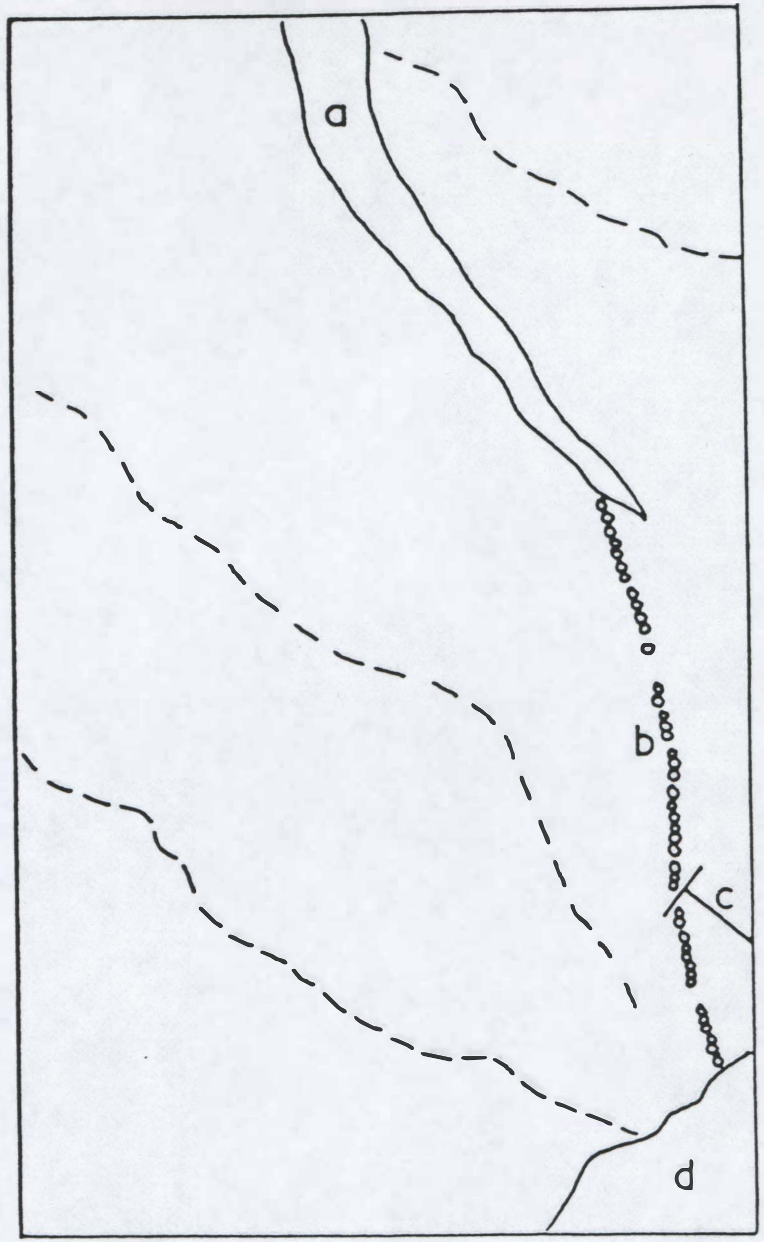

Fig. 3 Record of a possible ball lightning event obtained with Prairie Meteorite Network camera. The photograph is not framed parallel to the ground and the background lightning flashes are not thought to be associated with the event. The photograph appears to show a ball falling slowly to the earth in about three seconds from a somewhat unusual stroke, the ball track being cut into short segments by the $13\frac{1}{3}$ Hz switching shutter of the camera. The line drawing indicates the major features of the photograph (a) lightning stroke (b) ball images (c) telephone pole (d) ground

lightning flash would be recorded in its entirety or not at all, but a slow-moving lightning ball would yield an image consisting of a series of discrete blobs. After careful searching they discovered a number of such records (Tompkins & Rodney 1980); an example is shown in Fig. 3. Some of these records may be of bead lightning but several can be interpreted as BL with characteristics which agree well with those established by eye-witness reports. Rather shorter-lived, ball-like luminosities have also been recorded during studies of triggered lightning by Fieux *et al.* (1975) and in video records of normal discharges by Eriksson(1977).

Thus the photographic evidence in the main corroborates but does not amplify the eye-witness reports. The general paucity of such evidence is quite compatible with the apparent frequency of ball lightning and the ranges over which it may be expected to be observed. Desirable though spectroscopic and other forms of analysis of the balls might be, it seems highly unlikely that such measurements can be achieved in any systematic way on a reasonable timescale. As already noted, the after-effects of the balls are more accessible and can, for example, serve to give some idea of their energy content, of chemical residues or of radioactivity.

THEORIES

It is clear that our meagre and imprecise knowledge of ball properties provides few constraints for the fertile mind of the enterprising theorist. Thus, for example, we find the objects being assigned temperatures ranging from 300 to more than 10^4K, with with a consequent wide divergence in the subsequent explanations of ball origin.

However, among the hundreds of papers that have been written on the subject, it is possible to distinguish two broad classes of theory. In the first of these the energy required to sustain the ball throughout its life is acquired at the time of its origin and the object survives until this stock of energy is exhausted, A major problem here is the observation that the size and optical output of most balls stays relatively constant throughout their life, rather than shrinking steadily. In the second class of theories, some long-lived outside source of energy, usually associated with the electrification of the thundercloud, is assumed to continuously feed energy into the ball during its life; events observed inside conducting enclosures, such as aircraft, seem to present major problems for this class of theory.

Some of the variations of these basic models will now be briefly sketched in, together with their limitations; more details will be found in the review articles cited earlier.

One popular idea is that ball lightning somehow develops out of a normal lightning discharge. The latter obviously provides an adequate source of energy and the event shown in Fig. 3 appears to be quite compatible with the suggestion. In many versions of this idea it is assumed that a vortex structure develops, which somehow stabilises the object during its relatively long observed life (e.g. Endean 1976); it may be significant that rather similar luminous forms are observed in the vicinity of whirlwinds, cyclones and tornadoes, while the spinning appearance often commented on by eye-witnesses of ball lightning also supports this hypothesis.

Chemical theories also depend upon an initiating stroke, the basic mechanism being that a concentration of gases is rendered self-luminous by the flash. Oxygen, ozone and oxides of nitrogen are preferred by some authors, while others implicate naturally-occurring concentrations of hydrocarbons at favoured locations in the air. Closely related to these ideas are theories based on the liberation of combustible gases and other materials at the impact point of a lightning flash. All these theories have obvious difficulties in explaining those events where no preceding flash is observed. It is also difficult to see why any resultant luminosity should be localised as a sphere or why any hot gases should not tend to rise, giving the balls a predominantly upward motion.

Theories involving the ionisation of air or water molecules have also proved popular, the ionisation energy providing the initial energy store to fuel the ball's luminosity. A problem here is that recombination should occur very quickly, but Hill (1960) has proposed that recombinations can be slowed if the ions are attached to dust particles and other fragments of foreign material. Various processes, including small internal coronal discharges between the local ionised regions, would then contribute to the ball luminosity. Again, it is difficult to see why a mechanism of this type, if it is effective, should not generate luminosities all along the track of the lightning stroke, rather than a localised sphere.

More exotic are nuclear theories, involving either the creation of the radioactive isotopes ^{15}O and ^{17}F by the lightning discharge (Altschuler *et al.* 1970) or even anti-matter micrometeorites (Ashby and Whitehead 1971). Fascinating though such theories are, they predict radiation after-effects that have so far not been reliably detected.

Turning now to the other major class of theory, where an external source provides a continuing energy input to the ball during its lifetime, two main suggestions have been put forward. The first of these pictures the ball as a localised, spherical, low current, glow discharge in an atmospheric DC field. The sphere is visualised as a region of conducting gas which produces a local convergence of the electric lines of force and current. The increase in electric field and current density gives the glow discharge and maintains the ball's conductivity. This basic model, due to Finkelstein and Rubinstein (1964) has been investigated in a quantitative way (an unusual exercise for ball lightning theories) by Uman and Helstrom (1966) who showed that a ball of plausible characteristics could be produced. Further refinements in the basic theory have been made by Powell and Finkelstein (1970).

The other major theory of this type invokes electromagnetic standing-wave patterns for the formation and sustenance of the ball. Although several earlier authors refer briefly to the idea, it seems fair to credit its first real development to Cerillo (1943) and its popularisation to Kapitsa (1955). Briefly, it is envisaged that the reflection of storm-induced electromagnetic waves from the ground or other obstacles might set up a standing wave pattern. At the antinodes of this standing wave field, the electric field intensity would be such as to cause ionisation to occur and a luminous sphere would start to grow. With an observed BL diameter of about 30 cm, it would be expected that the electromagnetic radiation would need to have a frequency about 300 MHz. Unfortunately, while this model has provoked vigorous theoretical activity, measurements in the vicinity of thunderstorms have so far failed to produce any strong evidence for the existence of narrow band radiation with the characteristics required. Nevertheless, laboratory studies with microwave excitation have demonstrated that it is possible to produce quasi-spherical luminous regions in a variety of gases by this type of mechanism and that, moreover, some of these regions persisted for up to two seconds after the exciting radiation was turned off.

DISCUSSION

It seems fair to say that observations of naturally-occurring BL in the last hundred years have added surprisingly little to our knowledge of the phenomenon, although there is no doubt that they confirm its reality. Unhappily, while studies of the normal lightning discharge have been spectacularly advanced by systematic objective observations at sites which have a high probability of being struck, such as the Empire State Building, no-one has yet identified such a site for BL. Thus the prospects for the collection of physical measurements of ball lightning parameters seem bleak. The best that can be hoped for is that, by trying to ensure that BL reports are gathered with minimum delay, it may be possible to assess more exactly any damage or other residues left by the balls and to maximise the accuracy and information content of the eye-witness records. Statistical analysis may then clarify the long-standing question of whether BL is a single phenomenon with a unique origin or whether it represents a whole class of phenomena, having diverse modes of formation and sharing only the common feature of producing a mobile luminous object in the atmosphere.

More promising, perhaps, are the prospects for furthering our understanding of BL through laboratory studies. As Singer (1980) has recently pointed out, it is known that luminous objects with at least some of the characteristics of BL can be produced artificially by a variety of methods. The precise physical conditions for the formation and stabilisation of such objects remain largely uninvestigated. It may be, then, that it is in the laboratory rather than in the natural environment that progress in solving the stubborn riddle of ball lightning will next be made.

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BALL LIGHTNING AT CRAIL – 1968

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AN unusual ball lightning (BL) event occurred in early August 1968 at Crail, a small seaside town in the East Neuk of Fife, Scotland. The account is of interest not merely because there were so many witnesses, but because one of them saw the BL form, it caused damage, and the event occurred under a clear sky.

WEATHER CONDITIONS

The incident is thought to have occurred on 5 August 1968, although this has not been established without doubt. The time was mid-afternoon, probably around 1500 BST. Witnesses' recollections of the weather differ; to some it was a hot, sultry

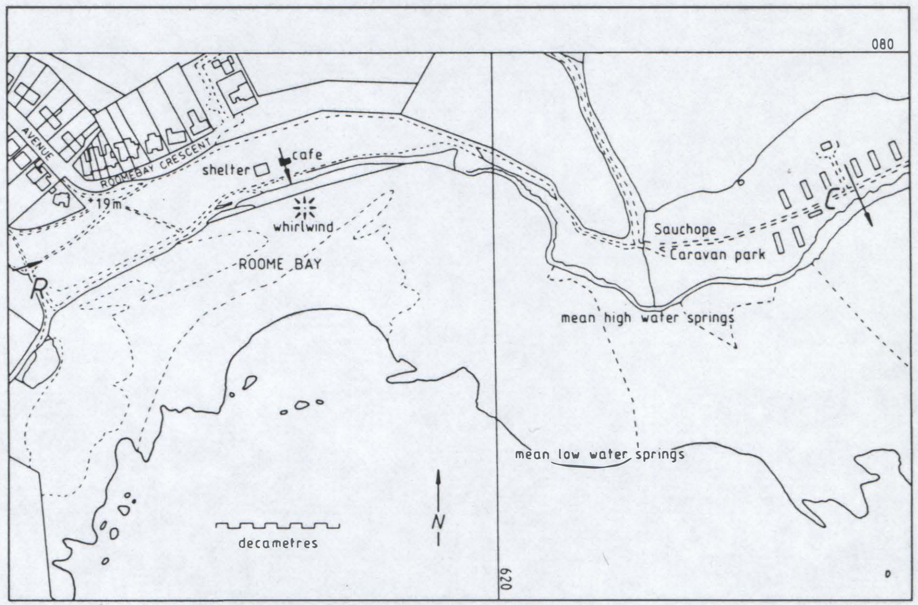

Fig. 1 Location of BL event at Crail. The arrows indicate direction of movement of the BL

and oppressive day, while to others it was fine and summery. One resident of Crail (Mr Radcliffe), who did a postal delivery round in the morning, says that while he was out it had been sunny with a thick heat haze on the sea. As the sun reached its zenith this haze became even denser, the sky taking on a coppery hue 'of the type one expects when thunder is around', and he found that the humid air hampered his breathing.

The records of the nearest meteorological station (RAF Leuchars, 20 km to the north-west) show that conditions were as follows: temperature 17°C (dewpoint 14°C), low stratus cloud 5/8 at 200–300 m, visibility 24–30 km, pressure 1023 mb, wind from the east at 4–5 ms^{-1}. Thunder and lightning were recorded at about the time of the incident, but not at Prestwick, 150 km to the west. The above temperatures give a relative humidity of 90 per cent and a vapour pressure of 17–18 mb.

THE WHIRLWIND

The event took place at Roome Bay, a popular and busy holiday beach (see Fig. 1) just to the east of the town. At about the centre of the beach an evangelical mission meeting was in progress, but it was suddenly disrupted by a violent whirlwind, which hurled several deckchairs and other loose items into the air and dropped them some 50 m down the beach towards the sea. It seems that this event caused many people to leave the beach.

THE FORMATION OF THE BALL LIGHTNING

Elizabeth Radcliffe was walking along a shore path at the west end of Roome Bay ('R' on Fig. 1). She was looking down at the path in front of her but became aware of a shimmering brightness coming towards her from the left. She looked up and could see no definite shape to the brightness, but as it approached she saw a round shape trailing several lines of light (see Fig. 2). This object crossed the path about 6–10 m in front of

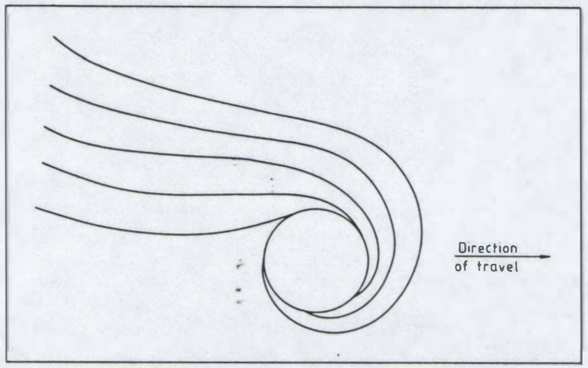

Fig. 2 The appearance of the BL as seen by Elizabeth Radcliffe

her from left to right (west to east). By the time it reached the path, the lines of light had rolled up 'like a ball of wool' into the BL which had a diameter of about 20 cm and was about 0·5 m above the ground. Since the object appeared grey while over the path but green while over the grass either side, Mrs Radcliffe believes that it was translucent. However, it might have been reflective. Having rolled up, the object was more dense and compact. Although it had the luminosity of a 100 W tungsten lamp, neither heat, smell nor sound was detected. The BL rolled on a horizontal axis in the direction of motion. After being in sight for only a few seconds, it quickly disappeared over a slight rise in the ground to Elizabeth's right. Almost immediately she heard a very loud noise like an explosion. This noise woke her husband Gilbert who had been asleep in their home 100 m away (although he was about 320 m from the assumed source of the explosion, see below). It reminded him of the noise of an exploding sea mine, some of which are washed up on the shore occasionally. Shortly afterwards he heard a great many people rushing past his house as they fled from the beach. Some sounded shocked and were talking loudly, while others were crying. The crowd included about 30 young people who had been attending the beach mission service, the leader of which was heard to attribute the event to a divine demonstration!

THE EXPLOSION AND DAMAGE

Evelyn Murdoch and her daughter Jean Meldrum kept a small cafe just east of the public shelter and toilets at the centre of the promenade (see Fig. 1). Alarmed by loud crackling and hissing noises, Mrs Meldrum went outside to the front of the cafe where her baby son was in his pram (see Fig. 3). Suddenly there was a very loud noise like a

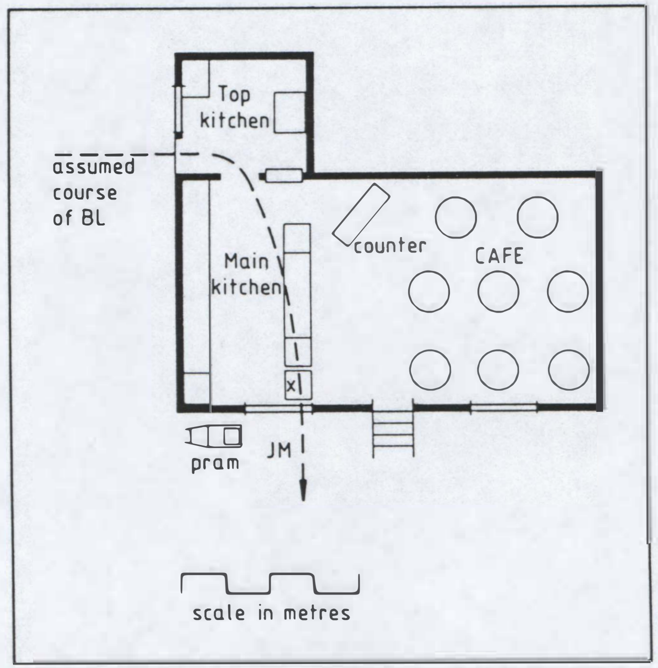

Fig. 3 Plan of Mrs Murdoch's cafe
X = damaged cooker
JM = Jean Meldrum

whip crack; it made her think that the whole cafe had split. Immediately she saw the BL emerge from the open kitchen window above her. It was a fluorescent orange sphere about 25 cm in diameter, surrounded by a white halo and projecting rays. It was very bright and illuminated the whole cafe. As it passed, it struck her a glancing blow on the chest. It disappeared in the direction of the beach, where the whirlwind had occurred. At the noise, all the cafe's customers fled, and the cafe closed for the day.

Mrs Meldrum suffered no damage to her person or clothing although for a short while afterwards she did feel as if she had suffered a blow on the chest and she consulted her doctor.

Mrs Murdoch had been busy collecting wind-breaks from people who were leaving the beach; in their haste they threw them in at the door of the cafe. Thus she was in the main cafe when she heard the loud crack. She took some wind-breaks into the kitchen to fold them up, but as she entered the kitchen she noticed with surprise that it was very brightly illuminated, as if it were hot! The normally dark roof and rafters were starkly lit up and the whole room was a luminous white. This effect, which frightened her, lasted for a few seconds, and then faded.

Irene Greig, who was serving in the cafe at the time, saw nothing unusual, but did hear the crackling noises.

Only when Mrs Meldrum and her mother opened the cafe the following day did they discover that the pot stand of a small table-top gas cooker was split into two parts. The BL had passed directly over this cooker and was above it when the loud crack occurred. Although the stand was subsequently repaired by the local blacksmith, both stand and cooker were later disposed of. In fact the cafe itself no longer exists. Attempts to identify this cooker have proved unsuccessful. Mrs Meldrum states that at the time of the incident the cooker is likely to have been lit. Since there was no smell of gas when they re-entered the cafe, she presumes that the explosion had not extinguished the gas flame. A tea urn had been sitting on top of the cooker.

THE DEPARTURE OF THE BALL LIGHTNING

Kathleen Cox, a retired teacher, was walking two dogs eastwards through Sauchope Caravan Park (see Fig. 1) when she heard what sounded like a tremendous clap of thunder. This was followed by children's screams, and the appearance of a BL travelling southwards between the caravans. It crossed the path in front of her and disappeared out to sea. The BL was about 20 cm in diameter, a dirty copper colour, trailed what looked like a 5 cm wide ribbon of copper, and made a whirring noise. It appeared to be rotating on a horizontal axis, clockwise as viewed by the witness, and was about 1·5 m above the ground. One dog which was unleashed, ran ahead in terror; the other, leashed, strained to follow and pulled Miss Cox rapidly away from the scene. When she reached Fife Ness, just over 2 km away to the east, she found that all the golfers on the adjacent course had been driven into the clubhouse by torrential rain, and that it was dull with low cloud. It appeared that the downpour had occurred at about the same time as the BL at Crail.

CONCLUSIONS

While there must have been very many eye witnesses, accounts have been obtained from four only, of whom only three saw the BL. At the time no-one appears to have reported the event to the press or the police, and the witnesses express surprise that the event is either rare or of scientific interest. Despite the fact that investigation was carried out 11 years after the event, the witnesses' memories seem undimmed. All except Mrs Greig still live in Crail.

The three separate accounts may be related to each other by means of the explosion, which is assumed to have been the event which cracked the pot stand. It is assumed that the loud crack heard at the cafe was the same noise heard as an explosion by Mr and Mrs Radcliffe, and as a thunderclap by Miss Cox. Thus it is assumed that only one BL formed and that it was this same object that was seen by all the witnesses. The colour variation is consistent with a BL which formed in front of Mrs Radcliffe and was decaying as it passed in front of Miss Cox. It is interesting that the BL appears to have produced sound only in the latter stage. It is assumed that the BL entered the cafe via an open door or window at the rear; it is known that all these doors and windows were open.

The accounts are valuable additions to our knowledge of BL and indicate that it may be more frequent than is usually supposed. This event came to light by chance.

NOTE: Ball lightning is also featured in Letters to the Editor on p. 90

EXTREMELY LOW TEMPERATURES OVER ENGLAND AND WALES OBSERVED BY METEOSAT 2

The picture on the cover shows a digital false colour infra-red image from the European geostationary satellite Meteosat 2 obtained at 1800 GMT on 12 December 1981. Pictures such as this are received every half-hour using the Primary Data User Station (PDUS) facility at the Meteorological Office Radar Research Laboratory, Malvern, where they are displayed in National Grid format on a television monitor within eight minutes of the nominal data time.

On this occasion, most of England and Wales was snow covered and the sky was clear. Although some parts of central England were foggy, the temperature inversion was shallow, absolute humidity was low and errors in remote sensing of surface temperatures due to atmospheric absorption were small. Comparison of several images received on the day in question with the screen temperatures at synoptic stations in England and Wales showed that the black areas represented temperatures mostly near or above 0°C. The areas coloured yellow had temperatures of the order of −2°C, green −4°C, cyan −6°C, blue −8°C, mauve −10°C, red −13°C and white represented areas colder than −15°C. The extensive white area in the west, on the left of the image, was from the high cloud which moved eastwards to cover most of the British Isles by 0900 GMT the following day.

Record low temperatures occurred over several parts of central England during the early morning of 12 December and again on the subsequent night, particularly in the areas of the south and west Midlands. These areas appear white on the 1800 GMT image. At Shawbury, in Shropshire, the screen temperature was already −22°C at this time and it fell to −25°C before the advancing high cloud and strengthening winds caused a general rise in surface temperature.

Meterological Office K. A. BROWNING
Radar Research Laboratory
Malvern

METEOROLOGICAL BROADCASTS – A REQUEST FOR INFORMATION

Later this year it is hoped to publish an article giving details of meteorological broadcasts and providing some information on the equipment that may be required for the reception of such broadcasts. Readers who have purchased or built equipment to receive radio-teleprinter or radio facsimile broadcasts, or to receive the transmissions from the weather satellites are invited to write to the Editor and provide some details that will be useful in the compilation of such an article. Details required include the make and type of equipment, some indication of the cost and the reliability of the units, and some details of equipment if home-made (sources of technical data and so forth). Information on second-hand sources of equipment would also be valuable, as would knowledge of the broadcasts which are received, the data which are found to be of most use, and any difficulties encountered.

Letters will be treated in the strictest confidence and the information used only for the compilation of the article. Replies should be addressed to: The Editor (Meteorological Broadcasts), Weather, Royal Meteorological Society, James Glaisher House, Grenville Place, Bracknell, Berks. RG12 1BX. Replies would be appreciated before the end of April. Overseas readers are also invited to respond even though their replies may not reach us until after the April deadline.

'WEATHER' MARCH 1982 P Christie

point of obscurity. We read, for example, in Chapter 8 'The importance of spatial frequency is that the distance of a point in the diffraction pattern from the origin corresponds to a particular frequency. . .' Given the problems that newcomers to these fields may be expected to have, and that the purpose of the book is to make their life easier, a somewhat more considered and careful editorial stage in its production would, perhaps, have been beneficial.

Against these criticisms must be set the generally high quality of the printing and presentation. Diagrams and plates are clear, although occasionally marred by inadequate labelling (which picture is Fig 8·3(b)?), and often without the benefit of scales. The references cited are generally up-to-date and would perhaps prove one of the most useful facets of the publication to those involved in research. They seem, however, to be dearly bought at more than £1·00 per chapter.

R. E. W. PETTIFER

LETTERS TO THE EDITOR

Correspondents are requested to observe the following rules when submitting letters for publication: the material should be typed or clearly written on one side of the paper only: it should carry ample margins at top and bottom as well as each side of the text: typed matter should be double line-spaced.

Ball Lightning

In response to the interest shown by readers in ball lightning we have published in this issue an up-to-date review of the subject. Also in this issue are a detailed account of a Ball Lightning event in Scotland and three further letters published below. Particularly intriguing is the letter from M. C. Jackson, describing an event apparently identical to one included by Dr Charman in his review.

EDITOR

After the letters on ball lightning (*Weather*, **36** (5), pp. 155–156) readers may be interested in a rather bizarre incident which my aunt still vividly remembers and describes.

It was a hot summer's day about 1916 or 1917, and there was a severe thunderstorm at lunch time. My aunt was travelling by electric tramcar from the town centre of Newcastle under Lyme to May Bank in the thunderstorm when a red glowing ball appeared at the back door of the tramcar. This ball drifted down to the front of the car and then out of the front door. The ball travelled at walking pace down the car, was the size of a football, moved at head height between the seated passengers, made no noise, caused no damage (except to the nerves of the passenger), and once outside the tram, it broke up and disappeared (like a red balloon bursting).

Bracknell,
Berkshire

M. C. JACKSON

I read in a local newspaper, *The Nation*, the following account of an interesting case of ball lightning in the Langata suburb of Nairobi:

A Nairobi woman was woken by a strange noise in the night. And when she opened her eyes, the thing she saw made her dive under her blankets in fright! It was a burning disc, about the size of a plate, hovering around the door. When Mrs Charity Muthoni Benson plucked up the courage to take a second peep from under the blankets, the strange object was sparkling round the edge, and was beginning to shrink to the size of a small ball. It was rotating, slowly. There was a blue fire in the middle of it. There was heat coming from it. Eventually it disappeared completely, leaving a cloud of smoke that didn't disperse, but started to move around the room. Finally it went through the door towards the kitchen. Mrs Benson stayed 'right where I was' for several minutes before deciding to call her sister, Mrs Lucy Kariithi. She didn't have to wake her sister up. She was wide awake and just as frightened. She had heard the humming noise too. 'I thought perhaps I'd been dreaming', Mrs Benson said, 'but my sister's experience proves I was not. We looked for the smoke in the kitchen but it wasn't there. We wanted to call somebody . . . ask somebody. We decided to phone the *Nation*', Mrs Benson said.

Nairobi,
Kenya

T. S. CHAGGAR

During the years 1934 to 1938 my home, situated in the Vale of York, was struck by lightning three times, and each time ball lightning was involved. The house is situated in the middle of the village of Seaton Ross, it is adjacent to the church which has a tower with lightning conductor. The village school lies even closer than the church and is twice the height of the house. Telephone wires in those days were suspended fairly close to the house, crossing the garden. All these facts are believed to be relevant.

The first 'strike' in the summer of 1934 involved only a small amount of damage; it was witnessed by the junior school mistress. There was a lightning flash, and immediately after a 'ball of fire' travelled slowly along the telephone wires, appearing to be riding on the top of them. It then 'floated' to our nearby wooden 'wireless' pole and shattered the top quarter. No damage was done to the radio which was always 'earth switched' at the sniff of a thunderstorm.

The next incident was possibly in 1936. I witnessed this while in school. During a thunderstorm there was a vivid flash and then I saw a ball of light floating towards my house. It just vanished near the chimney. What happened inside the house was different. Apparently the 'flash' or 'ball' travelled down the chimney without damaging the pots, flashing across the living room cracking the brick wall opposite and ripping off plaster and wallpaper. My mother, who was walking in front of the fireplace at the time, received a severe shock and a large burn on the front of the leg. Soot poured down the chimney.

In, I believe, summer 1938, worse was to follow. The sky to the south-west became really black. I was in the living room with my mother; my father was in the school nearby. He saw how dark the sky looked, and was returning home (only a few yards) when the first lightning flash occurred. He saw a flash then a vivid ball drifting slowly to the house chimney stack which it struck. The stack with two pots collapsed taking half the roof with it. Meanwhile inside, the living room was filled with a vivid blue flash; pans on the fire were flung onto the hearth. It was such a vivid flash that we were temporarily blinded. The damage was severe apart from the chimney stack and roof. Every joint in the metal guttering was broken. All the bedroom curtains which were suspended on metal wires lay in smouldering heaps, the metal apparently having been heated to a very high temperature. It appears that the ball of lightning 'burst' inside the chimney breast in between two bedrooms, making holes like cannon shell holes in the brickwork. A wardrobe in front of the chimney breast was flung onto a bed.

It seems incredible that with much higher buildings and trees in close proximity my home should be struck three times. A local geologist suggested that a mineral deposit known to exist in this part of the Vale of York could possibly be near the surface at this point. Could it also be that *most* flashes produce a highly charged ball of electricity? Three out of three at one point seems to suggest this.

Brentwood,
Essex

W. PRESTON