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Long-lived light phenomena in the atmosphere

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Abstract. The state of knowledge of long-lived light phenomena in the atmosphere is reviewed in the light of contributions to the International Interdisciplinary Congress on Unsolved Problems of Atmospheric Electricity, September 1993, Salzburg, Austria; and the First International Workshop on Unidentified Atmospheric Light Phenomena, March 1994, Hessdalen, Norway.

Two international conferences on light phenomena in the atmosphere have been devoted to different aspects of this problem. Nevertheless, in order to provide an idea of the present state of the research into puzzling phenomena in the atmosphere, it makes sense to analyse them jointly because they complement one another. The first conference, held in Salzburg, was devoted to the problem of ball lightning, but as regards its spirit and the nature of the problems discussed it differed appreciably from the international symposia on ball lightning [1–3] which have been mainly concerned with the question "What is ball lightning?" In addition to physicists, specialists from technical professions — electrical and power engineers — as well as representatives of the humanities — journalists, historians, and psychologists — participated in the work of the Salzburg Conference. The organiser and Chairman of the Organising Committee of this conference was A Keul — Professor of psychology at the Salzburg University. The character of the conference was largely determined by the nature of its participants. The term 'Vizotum-93' applied to the conference is associated with one of the folktales in the western part of Upper Austria. This tale describes the fiery circle Vizotum, the activity of which resembled that of the devil. It held no fear for those who prayed; for others it was dangerous to encounter it. Such was the fate which overtook a timid young shepherd who vanished after meeting the red fiery circle — the devil — which appeared after a sound resembling a thunderclap. All that was left of the shepherd were his clothes.

Myths, legends, and folktales of various nations contain interesting stories about ball lightning which originated many generations ago. As part of the national culture, they, as well as the way in which our remote ancestors interpreted ball lightning, merit careful study. Various questions arise in this connection, in particular why among some peoples ball lightning represents devils, whilst among others it is associated with angels. Another range of problems refers to the interpretation of ball lightning by the observer. The questions posed by psychologists are important for physicists because they throw light on the reliability of the descriptions of ball lightning and such descriptions constitute the basis for the understanding of its nature. These and other problems were considered at the conference and are described in its proceedings [4]. A list of the reports presented at the conference can be found in a brief review [5].

Another range of problems dealt with at the conference was associated with the existing storm protection systems in Austria and Germany. Personal experience and good quality photographs of linear lightning in the instant of electrical breakdown are of interest also for the analysis of ball lightning, including the method for protection against it. These technical aspects occupied a clear-cut place at the conference. Photographs of linear lightning were supplemented by interesting photographs of bead and ball lightning. A photograph of ball lightning taken by Burger Werner two years before the conference in the Austrian Alps occupied a central place among them. In fact, this photograph became the emblem of the conference.

Problems associated with the study of the physics of ball lightning and of its nature were given special exposure at this and the following conference. The level of the reports varied. However, if one compares the present state of the problem with the conditions at the beginning of the international cooperation on it (it would be more correct to choose 1988 as the starting point when the Japanese scientist Y Ohtsuki organised the First International Symposium on Ball Lightning), progress in the study of ball lightning has been quite remarkable. I shall not analyse the material presented at the conference dealing with the physics of ball lightning but shall consider the general state of the problem and advances made in recent years.

Study of the physics of ball lightning can be divided arbitrarily into three parts: (1) collection and analysis of observations of ball lightning; (2) modelling of ball lightning as a whole; (3) special physical studies, the results of which make it possible to analyse individual aspects of the physics of ball lightning, and analysis of individual aspects of this phenomenon.

Observations of ball lightning constitute the basis for its further study. New sets of observations continue to appear, including the Salzburg conference report by K H Hentschel, who collected 130 observations of ball lightning in Germany. It should be kept in mind that several thousand descriptions of observations of ball lightning have been collected so far, so that it is not so much the number of observations but the quality of the

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data and their treatment that is of primary importance. One may quote as an example the Russian – Austrian data bank or the Stakhanov – Bychkov – Keul [data] bank, which in recent years has provided the greatest amount of information on observed ball lightning. This bank includes approximately 1500 descriptions collected by I P Stakhanov, 100 descriptions collected by V L Bychkov, and 150 descriptions reported by A Keul. The interpretation of these data must take into account the limited accuracy of each particular description. Furthermore, standard mathematical approaches do not work here because the distribution of ball lightning with respect to parameters is not a normal distribution. For this reason, the data bank includes also a set of IBM programs which make it possible to handle the information. These programs are based on standard programs which permit a statistical treatment of data and at the same time include additional elements. Since the creation of a data bank is necessary in the study of any atmospheric light phenomenon, and in this respect the experience gained on ball lightning by the existing bank is useful, the concepts involved in the mathematical procedures on which the bank is based, developed by A Yu Strizhev, are summarised below in Appendix 1. A more detailed description is provided in A Yu Strizhev's report at the Hessdalen conference.

As regards the experimental modelling of ball lightning as a whole, there have been tens of experiments related to the observation in the atmosphere of particular glowing formations resembling ball lightning. This indicates the possibility of excitations in the atmosphere leading to the generation of ball lightning. However, these experiments contributed nothing to the understanding of the nature of ball lightning in view of the complexity of this phenomenon.

On the other hand, modern ideas on the nature of ball lightning are based on the study of individual processes and phenomena which are not associated with ball lightning but whose detailed understanding helps to elucidate individual elements of the nature of ball lightning. Ball lightning is a many-sided phenomenon, so that different models may be useful for the description of its individual aspects. For example, flat iron is a somewhat unexpected and therefore instructive model of ball lightning if one is interested in heat sensations at a certain distance from ball lightning. A flat iron is characterised by approximately the same dimensions and specific energy evolution as the average ball lightning, so that with its aid it is easy to model the nature of heat sensations at a distance from ball lightning. Another example of this kind is the analysis of the gas dynamics of ball lightning carried out by N I Gaidukov on a simple model for the material of ball lightning — an ideal liquid with a low surface tension and low specific gravity. This model makes it possible to analyse various properties of ball lightning, such as the conservation of its shape during motion, its ability to squeeze through small apertures and slits, and its capture in the trail of a moving object, for example an automobile or an aeroplane. Comparison of the observed facts and estimates demonstrates the absence of resistance in the surface layer. This shows yet again that ball lightning consists of elements of small size. Different models are thus useful for the analysis of individual aspects of the nature of ball lightning.

Despite the multiplicity of models capable of describing the properties of ball lightning, the central question concerning the nature of ball lightning is related to its structure. The understanding of this question is based on the study of processes occurring in laser-induced vaporisation of matter, processes leading to the evolution of beams containing solid clusters of nanometer dimensions, as well as the study of certain types of erosion plasma. The substance of ball lightning is formed as a result of the combination of nanometer clusters into rarefied structures. By virtue of the high degree of rarefaction, the substance of ball lightning exhibits simultaneously the properties of a gas, a liquid, and a solid and this new quality of ball lightning as a physical object explains its unusual properties. The substance of ball lightning can become compacted after a time, which leads to its irreversible ageing. Thus the substance of ball lightning is an unusual physical object, and more information about it becomes available as various physical systems and processes unrelated to ball lightning are investigated.

Despite the schematic understanding of the nature of ball lightning and also the usefulness of different models for the description of its individual aspects, certain postulates concerning the nature of ball lightning which do not stand up to serious criticism are being put forward at each conference. However, this problem has undergone a certain degree of development and there are simple rules for the rejection of many of the new hypotheses. Two examples may be quoted. When P L Kapitsa proposed 14 years ago a model of ball lightning maintained by an external source of UHF radiation, he reasoned approximately as follows. A high-pressure plasma is known to relax rapidly, i.e. its internal energy is converted into thermal energy after a short period. Therefore, in order to maintain the plasma for a long time (comparable to the lifetime of ball lightning), it must be supplied by an external energy source, one kind of which is UHF radiation. In particular, it follows from this reasoning that, if ball lightning is maintained by its internal energy, then its nature cannot be related to a plasma. Unfortunately, this is not taken into account in many of the new postulates.

Another example refers to the radiation from ball lightning. It follows from the interpretation of observations that the radiant temperature of ball lightning is of the order of 2000 K. At this temperature and at atmospheric pressure of the surrounding air, the decay time of the excited states is very short. Under these conditions, the source of the radiation should be in equilibrium, i.e. the radiant temperature should agree with the temperature of the emitting elements of ball lightning. Hence it follows, in particular, that the substance of ball lightning cannot be organic — it would burn away. Thus the problem of ball lightning has traversed a certain evolutionary path and we have now at our disposal a definite set of elements which make it possible to reject erroneous hypotheses.

It is clear that the understanding of ball lightning has advanced further than that of some other atmospheric light phenomena. One of these, called the Hessdalen phenomenon, was the subject of the second conference. Hessdalen is a valley in central Norway. In the valley there are about 100 houses. Its length is 12 km and its width is 5 km. A small river flows through it. The height of the mountains surrounding the valley is approximately 1000 m above sea level. Since 1981, the inhabitants have from time to time observed an intense glow during darkness. This glow has been called the 'Hessdalen phenomenon' [6]. It usually occurs in the evening, during the night, and early in the morning, most frequently in the Autumn, Winter, and early Spring, i.e. the dark period.

Three types of strange fires have been observed. The first resembles a bright yellow sphere or nucleus and can exist for 1 – 2 h, moving along the valley and changing its position at 5 – 10 min intervals. The second type has a bright whitish-blue colour and occasionally flickers. It is usually observed over the mountains. The third type consists of several fires linked to one another. The Hessdalen fires began to appear at the end of 1981 and were observed several hundred times between 1981 and 1984. They began to vanish in 1984, and in 1985 only a few instances were observed. Nowadays the Hessdalen fires appear rarely — about 30 events were recorded during the 1993 – 1994 Winter season. As a result of the efforts of scientists-enthusiasts, a 'Hessdalen project' was set up in Norway during 1983, the aim of which was to investigate this phenomenon with the aid of an assortment of modern instruments. These instruments included a video camera with a grid, an infrared sensor, a spectral analyser, a seismograph, a magnetometer, radar, a helium – neon laser, and a Geiger – Muller counter. The project included two periods of measurements: January – February 1984, in which 53 instances of a glow were observed, and January 1985, when not a single instance was observed. Several interesting results were obtained. For example, a laser beam aimed at the glowing object induces a double flash in the latter, while radar detects the glowing object by the reflection of the radar signal, which makes it possible to estimate the velocity of the glowing object. Yet another interesting result may be quoted. On one occasion, the glowing object left a track in the snow in the form of a spiral 2 – 3 cm deep. Analysis of the track showed that the number of bacteria in it was approximately 100 times less than in the region adjoining the track.

On the other hand, the measurements made are still insufficient to infer unambiguously the nature of the glowing formations, while the accuracy or statistical information are inadequate to allow further conclusions to be drawn. It was therefore decided to carry out yet another stage of the project in 1994 – 1998 under the heading 'unidentified atmospheric light phenomena in Hessdalen' and the conference is one of the measures undertaken in this connection. The report by E Strand, who was the organiser of the conference and the scientific supervisor of both projects, and Dr B G Hauge, who described the technique for the second 'Hessdalen project' occupied a central place at the conference. Special time was set aside at the conference for the discussion of methods of measurement and virtually every participant contributed some suggestions.

It is of interest that, within the framework of the first Hessdalen project, several strips of video films were obtained in which both the Hessdalen phenomenon and ball lightning were recorded. Analysis of these strips promises to yield interesting information about these objects.

Let me stress the special features of the 'Hessdalen project' and of the conference itself. In essence, this project is the first mixed-approach programme for the investigation of long-lived glowing objects in the atmosphere carried out at a high professional level consistent with modern scientific programmes. Therefore the importance of this project goes beyond the framework of a national scientific program and of the phenomenon under investigation. Secondly, atmospheric light phenomena of different nature may have more common features and it is therefore more appropriate to consider them jointly. For this reason, both conferences include not only reports on ball lightning and the Hessdalen phenomenon but also on other light phenomena in the atmosphere. One of these is gorgons — moving glowing objects resulting from volcanic activity. The American scientist E W Bach, an enthusiastic researcher of this phenomenon, carried out for this purpose expeditions into various regions of the world. The knowledge of many languages, including Russian, enabled him to collect interesting information of cultural-historical and scientific importance. Appendix 2 below comprises fragments from Dr Bach's report at the Hessdalen conference, which constitutes in essence a lecture on his journey to the Philippines.

In conclusion, I should state that the knowledge of ball lightning is in a more advanced state than that of other long-lived atmospheric light phenomena because more efforts have been devoted to it. Ball lightning has been the subject of scientific research for more than 100 years and thousands of scientific communications have been published on this topic. On the other hand, the 'Hessdalen project' provides a good example of an approach to problems of this type, including an array of measurements within the framework of an established programme as well as resort to intellectual values useful for such a programme. The experience gained in the study of both objects may be used also for other atmospheric light phenomena (for example UFOs) which are at a different level of understanding and investigation.

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Appendix 1

Principles of statistical treatment of data in data banks

A Yu Strizhev

We believe that, among the existing means for the control of data banks, the most convenient is Clipper 5.0. It makes it possible to set up independent statistical treatment programs which are convenient to use and can be conveniently transferred to another computer. This system may serve as a basis for the creation of a data bank.

Data banks for observations on atmospheric objects have a number of identical features: some degree of error in the information introduced by the observer, a large number of parameters, etc. Since the first feature affects the accuracy of the results, it is customary to represent the available information by histograms, i.e. in the form of tables in which a discrete distribution of the number of observations in the specified ranges of values of the parameters under consideration is represented, as well as correlation tables, i.e. three-dimensional histograms with respect to two parameters. The existing means for controlling data banks make it possible to obtain the results in such a form. The second feature (the large number of parameters) makes it laborious to construct such histograms because it requires that a separate program be written for each parameter. The experience gained in setting up the data bank for ball lightning has provided a series of simple procedures which make it possible to simplify these problems and to process large amounts of information. The concept underlying this approach will be described below.

A data bank is a file in which information is stored in the form of separate records. Each record represents a description of one object subdivided in terms of parameters (fields). In order to obtain the relevant histograms, a control program has been written in the Clipper 5.0 language. The interface, i.e. the means of supplying information to the user and receiving it from the latter, plays a major role in facilitating the employment of the program. The existing interface has been written on the basis of the DBEDIT( ) Clipper function. It represents the content of the data bank in the form of a table, the rows of which comprise the records of the data bank while the columns represent the fields. The user, moving the cursor along the screen, can place it on any record and on any parameter, selecting them thereby. Difficulties associated with the presence of a large number of programs for each parameter are thus solved by replacing these programs with a single program which carries out the statistical treatment of the parameter on which the cursor has been placed at the given instant.

The Clipper functions do not permit a direct construction of histograms. A program which initially indexes the data bank, i.e. arranges the records in increasing order if the parameter is numerical or in alphabetical order if the parameter is symbolic, has been set up for the construction of histograms. The so called index file is then established in which the records are arranged in the order specified above. This file is convenient for treatment in terms of the Clipper functions or another program written, for example, in SI. On the other hand, if the histogram is constructed for a symbolic parameter, then its construction requires the initial determination of a set of values of the parameter for which the computation is to be performed. For this purpose, the program indexes the field in terms of unique records, i.e. all those which are encountered, after which indexing is carried out with respect to all the records and the computation is performed.

Thus the operation is based on the general principles for the treatment of information used in the data bank for ball lightning, which are useful also in the construction of data banks for other atmospheric phenomena. These concepts are intended for the employment of the existing means of controlling data banks such as Clipper, dBASE, FoxPro, etc.

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Appendix 2

In the steps of St. Elmo

E W Bach

Two fragments from Dr Bach's article, which provide an idea about the observation of light phenomena at different times and in different places, are presented below:

1. The term St. Elmo's fire originated with Italian sailors in the Mediterranean Sea and with fishermen in the Bay of Naples. The volcanic Phlegraean Fields, the Vesuvius, and the Epomeo Volcano on Ischia surround the Bay. From the tips and flanks of Italian underwater volcanoes rose and still rise fireballs called Saint Elmo's. This is also what fishermen see today in the Philippine Islands: bluish-green or reddish lights settle on passing vessels, usually on the railing or the mast, after they have bubbled up from the sea. Little is known about Elmo the historic person except that under Emperor Diocletian, in about 300 ad, he was tarred and burnt in public. An 'angel' or a fiery object descended and carried the martyr bodily or as a 'soul', so the onlookers thought, back to Formiae where he had been a bishop. No witness was able to follow that 'angel' on its flight from Rome, south-westward for 120 kilometres, but a returning spectator of Elmo's execution probably heard the story of a similar 'fireball' that landed in his home town. This led the witness to assume St. Elmo's distant flight. Formiae lies at the foot of volcanic mountains that stand in an arc, 500 km long, from Florence to Naples.

From Italy sailors carried the worship of St. Elmo through the Mediterranean, where the 'cold fireballs' still bubble up from at least 100 undersea volcanoes. Spanish sailors brought the St. Elmo worship to the Philippines. Another legend tells about St. Erasmo, a bishop from Syrian Antioch, who was condemned to a 'frying death' between a red-hot iron seat and a glowing breastplate, but whom an angel carried off the execution stage to Illyria on the Adriatic Coast, 2000 km west from Antioch. The myths of St. Erasmo and St. Elmo merged into one (based on the *Acta Sanctorum*, retold in Butler's *Lives of the Saints*).

2. *Evidence of the eruption of the Philippine volcano Pinatubo, June 15, 1991, by the witness Reynaldo Ortega*:

We were 30 people who watched the morning eruption of Pinatubo, 7 a.m., June 15, 1991. Above Pinatubo there was a cloud five times higher than the mountain, that means 8 km high. The sky was already overcast with a high cloud veil that preceded the typhoon. But this veil did not hide Pinatubo. We clearly saw how it spewed the pitch-black cloud for an hour. At 7 a.m. the sky should have been bright, but we had a feeling of deep night. It was not raining. No flames rose from the crater to suggest any kind of combustion. But odd fireballs leaped from the crater at aeroplane speed and at all angles. Remarkably, they blinked: usually in intervals of half-second or faster, with vibration, or they blinked slower in intervals of seconds. The 'fireballs' issued short blasts like gun firings [gunfire], but not rolling thunder as we hear following a lightning.

Most 'fireballs' were brilliantly blue. The biggest must have been 200 m large, and their brightness hurt the eyes.

The balls changed rhythmically from blue to pinkish–red, then blinked out. Soon they blinked back on. We saw the biggest fireballs only in the first seconds, the medium fireballs in the first minute, and the smallest fireballs for the next five minutes. It did not seem the balls fell apart or burned themselves out; they quickly flew away. Only a few lightnings struck upward from the crater. Between flashes the crater was totally dark. Short hair–like lightnings spread from some fireballs like sparkling crowns. The fireballs were perfectly round and often left a glowing tail in flight. I do not remember green, orange, or gold–coloured fireballs.