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METEOR FIREBALL SOUNDS IDENTIFIED

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Abstract:

Sounds heard simultaneously with the flight of large meteor fireballs are electrical in origin. Confirmation that Extra/Very Low Frequency (ELF/VLF) electromagnetic radiation is produced by the fireball has been obtained by Japanese researchers. Although the generation mechanism is not fully understood, studies of MORP and other fireball data indicate that interaction with the atmosphere is definitely responsible and the cut-off magnitude of -9 found by Astapovich for sustained electrophonic sounds is supported by theory. Brief bursts of ELF/VLF radiation may accompany flares or explosions of smaller fireballs, producing transient sounds near favourably placed observers. Laboratory studies show that mundane physical objects can respond to electrical excitation and produce audible sounds. Reports of electrophonic sounds should no longer be discarded. A catalog of over 300 reports relating to electrophonic phenomena associated with meteor fireballs, aurorae and lightning has been assembled. Many other reports have been catalogued in Russian by Bronshten. These may assist the full solution of the similar long-standing and contentious mystery of audible auroral displays.

Instantaneously audible sounds associated with the flight of large meteor fireballs were first described by the Chinese in 817 AD (Astapovich 1951, LaPaz 1958). Edmund Halley (1719), in his description of a very large meteor fireball seen over England on the evening of 1719 March 19, was one of the first to distinguish the sounds produced instantaneously by a distant meteor fireball from the delayed sounds propagated acoustically. He wrote:"Of several Accidents that were reported to have attended its Passage, many were the effect of pure Fantasy; such as the hearing it hiss as it went along, as if it had been very near at hand:....But what is certain, and in no way to be disputed, is the wonderful Noise that follow'd its Explosion".

More than half a century later, in 1783, another very large fireball passed over England and the Secretary of the Royal Society, Charles Blagdon (1784), attributed the instantaneous sounds to "an affrighted imagination, or an illusion produced by the fancied analogy of fireworks." But because of the considerable testimony in support of such sounds, he decided that he "would leave it as a point to be cleared up by future observers".

In the year 1784 a physical solution was impossible: Auguste Coulomb had not yet developed his famous electrostatics law, and it was a further century before Heinrich Hertz demonstrated the existence of radio waves. Even when electrical discharges and radio waves became well understood, the solution remained elusive. The only evidence was anecdotal and the incidence of the sounds was highly capricious, sometimes being heard by only one or two members of a group of observers standing close to each other.

Leading meteor investigators in the first half of the present century, such as W.F. Denning (1907, and several other references) and C.C. Wylie (1932), were convinced that the anomalous sounds from meteor fireballs were purely psychological in origin, despite some well attested cases where the sounds clearly preceded the optical sighting of the fireball.

A Texas engineering professor, J.A. Udden (1917a), came rather close to the answer when he discussed the detailed observations which he collected of a large fireball. After analysing nine reports of instantaneous sounds, he concluded "If these observations are not subjective, the cause of the sound

may perhaps be sought in ether waves that, on meeting the earth, or objects attached to the earth, such as plants or artificial structures, are in part dissipated by being transformed into waves of sound in the air." This conclusion was evidently prompted by one observer who "seems to refer this sound to objects attached to the ground." (Udden 1917b).

As recently as 1979, leading meteor specialists still invoked a psychological explanation for the sounds, with the result that many potentially illuminating observations of the phenomenon were ignored and rejected from the literature (except in the Soviet Union). One revealing report of instant fireball sounds by a Cornell University radiophysicist eventually surfaced seven years after the event, in the New York State Journal of Medicine! (Ingalls 1967). The observer, Dr Bruce Hapke, who was with his wife, reported "The hissing and crackling noises were definitely associated with the meteor, although we cannot be sure whether or not they appeared to be coming from the meteor or from all around us. However, it can be stated with certainty that they did not appear to come from behind the meteor as they would have, had the object been a high-flying jet plane."

On 1978 April 7, at 4.44 a.m., a magnitude -16 fireball passed over eastern New South Wales (Keay 1980a), and hundreds of observers swamped the news media with reports. Of 36 reports investigated, no fewer than eight included sounds heard simultaneously with the fireball's flight, and a further two people heard sounds prior to sighting the fireball, or its glare.

A careful investigation of these reports (Keay 1980b) led to the following conclusions:

(i) Large fireballs produce electrical and/or electromagnetic energy in the Extra and Very Low Frequency (ELF/VLF) region of the spectrum. Previous spectrum searches had proved negative (Hawkins 1958a), leading to the comment "Meteors therefore show a surprisingly low efficiency in converting kinetic to radio energy" (Hawkins 1958b). However the ELF/VLF region of the spectrum was not examined by Hawkins during his search.

(ii) The generation of ELF/VLF energy by the fireball is at least partially explainable as the release of energy stored as "magnetic spaghetti" when the geomagnetic field is trapped and scrambled in the turbulent plasma wake of the fireball. Bronshten (1983) has confirmed that through this mechanism bright fireballs may produce radiated power levels of the order of kilowatts. For such a fireball the kinetic energy dissipation rate exceeds ten gigawatts.

(iii) The ELF/VLF energy is directly transduced into acoustic form by mundane objects which happen to be on or in the close vicinity of fireball observers. Early laboratory trials showed that rapidly varying electric fields produced rustling sounds audible by test subjects with appropriate hair styles or wearing glasses (Keay 1980c). Later laboratory tests showed that transduction by mundane artifacts, such as household items, and plant foliage could generate acoustic sound levels of up to 60 DbA from intense electric fields varying at audible frequencies (Keay and Ostwald 1991).

At any given location, the rare occurrence of large meteor fireballs makes it rather impractical to set up suitable instrumentation to record their ELF/VLF emissions. In the mid-1980s, after reports emerged of hissing sounds being heard during space shuttle re-entries over the American Midwest, attempts were made to tape them (Keay 1985) but this effort came to an abrupt end when the Challenger was lost. It will be interesting to try again, since overland shuttle re-entries have recently resumed for some missions. The incentive for doing so has now diminished, because crucial records of instantaneous fireball sounds have emerged from Japan.

Three cooperating groups in Japan have placed the emission of ELF/VLF energy from meteor fireballs beyond doubt (Watanabe, Okada and Suzuki 1988). For an exceptionally bright Perseid fireball they managed to obtain simultaneous photographic and radio records, together with an electrophonic sound report from a member of the photographic team. The radio emission lasted less than a fifth of a second, coincident with maximum light, when the fireball flared to a maximum brightness of -7 magnitude (Figure 1).

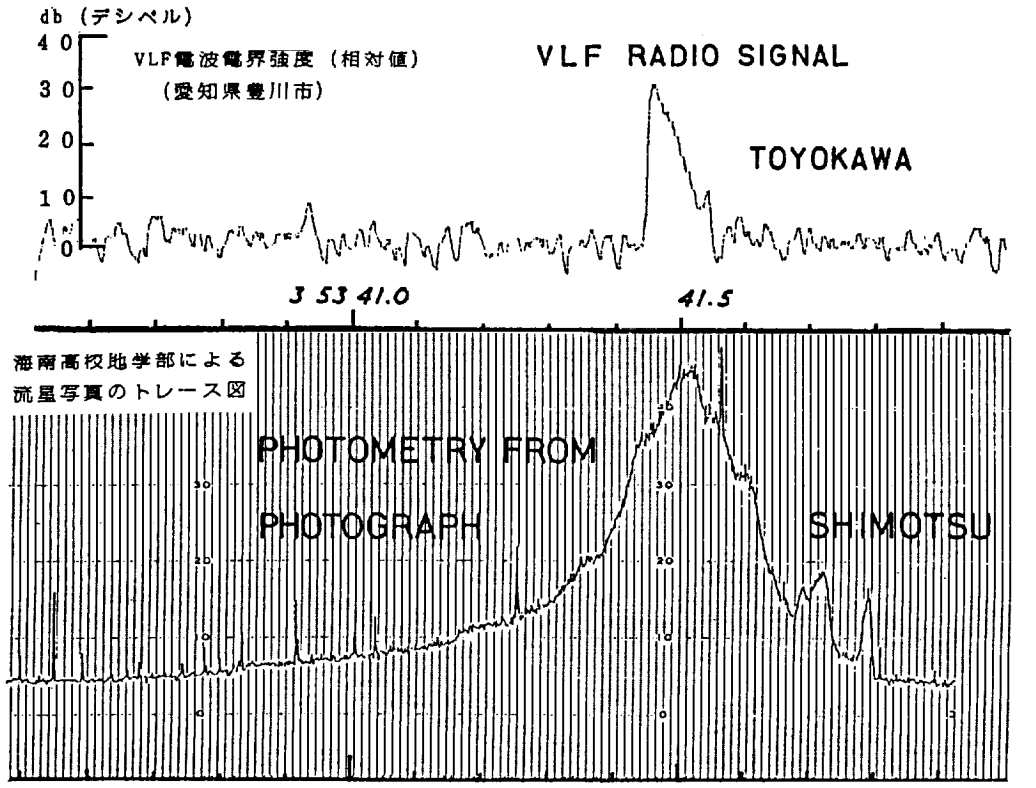

FIGURE 1 The Very Low Frequency radio signal recorded at Toyokawa, Japan, over 100 kilometres from a bright Perseid fireball photographed simultaneously from Shimotsu (courtesy of T. Watanabe and K. Suzuki).

Longer duration electrophonic sounds arise only from meteor fireballs brighter than -9 magnitude, according to leading Soviet meteor researcher, I.S. Astapovich (1958), who reached this empirical conclusion on the basis of an extensive body of observational evidence. A study of fireball light curves, obtained principally from the Canadian Meteorite Observation and Recovery Program (MORP) (Halliday, et al 1989, and personal communication), has verified Astapovich's result (Keay 1991b). The study indicates that the production of radio emission is dependent on the fireball penetrating the atmosphere to the point where continuum flow conditions prevail, at which stage a shock front is formed and turbulence arises in the plasma wake of the fireball.

The realisation and demonstration that intense radio emissions at audio frequencies are directly transducible into sound has provided an explanation for the immediate audibility of lightning strikes under favorable conditions. This may also hold for audible clicks derived from the electromagnetic pulse produced by a nuclear explosion. There is also the strong likelihood that the audibility of intense aurorae has a similar basis, but in this case the evidence for sufficient ELF/VLF electromagnetic or purely electrical emissions from aurorae remains very tenuous and is a challenge to researchers in that field (Keay 1990).

To ameliorate the scarcity of observational data on these phenomena, a catalog of over 300 reports of instantaneous audible sounds associated with meteor fireballs, lightning and aurorae has been assembled and is being expanded as data comes to hand. In a parallel endeavour, many reports have recently been catalogued in Russian by Bronshten, et al (1988).

A last comment. The advent of a viable physical explanation for the so-called "anomalous sounds" from meteor fireballs, and its acceptance, has led to a dramatic upsurge in the transmission of reports of these sounds (Keay 1991a). Hitherto such reports had been shunned and, since the scathing verdicts

of Denning and Wiley, only rarely mentioned in the literature. The same is still true for reports of auroral sounds. Hopefully the auroral research community may now take the matter of auroral sounds more seriously and give it the attention it rightly deserves.

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