Continued Progress in Electrophonic Fireball Investigations

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Abstract

The mechanism proposed in 1980 by Keay to explain the occasional observation of instantaneous electrophonic sounds from large meteor fireballs continues to gain support. This mechanism accounts for many of the empirical features of the phenomenon, and the detection of ELF electromagnetic waves by direct transduction explains various other geophysical electrophonic phenomena including early sounds from seismic events. The extension of Ceplecha's fireball model to include Revelle's criterion for turbulence leads to realistic estimates for the frequency of occurrence of electrophonic fireballs. It also appears possible that the type of electrophonic sound observed relates to the composition of the fireball.

Geophysical electrophonic phenomena may explain many baffling reports from ancient historical writings.

Keywords: electrophonics, meteor fireballs, bolide sounds

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Review of Recent Developments

A review of the state of knowledge of electrophonic meteor fireballs was published by Keay (1993a). Here we summarise relevant material which has appeared or come to attention since that review was written.

Maccabee (1994), responding to Keay (1993a), suggested that the photoacoustic effect may provide a better explanation for the anomalous sounds produced by large meteor fireballs than the generation and transduction of audio-frequency electromagnetic (EM) energy. His argument is non-quantitative and no mechanism is suggested for the required pulsation of the light from the fireball. The suggestion also fails to explain the production of electrophonic sounds by objects shielded from the light of the fireball.

Six electrophonic fireball reports from 1957 to 1990 have been published by Maslenitsyn and Voronina (1992). Five of them were entirely typical, the sounds described being of the normal hissing and/or crackling type. These types of sustained sound are representative of the smooth and staccato classes of sound respectively, as classified by Keay (1993b). However the observer of a fireball of nearly two seconds duration from Abakan, Russia, in 1982 did not specify the type of sound but

Earth, Moon, and Planets **68**: 361-368, 1995.

did state that "The sound appeared after the fireball disappeared, 0.5-1 second later." Did cloud obscure the end of the flight? Two seconds is unusually brief for an electrophonic fireball which produces sustained sounds.

A magnitude -11 fireball observed from the Flower and Cook Observatory, Philadelphia, on 29 April 1985 (Holenstein 1992) produced electrophonic sounds which were heard by some of those present during and just after the event. This fireball was reported in the April 1985 SEAN Bulletin, but the electrophonic observations reached the bulletin too late for inclusion.

Pugh (1993) reports that the 1992 February 24 fireball over Coos Bay was one of the brightest on record in the State of Oregon. It lasted 5 or 6 seconds. The electrophonic effects were widespread, ranging from making a house "tremble" to hissing from a chain link fence. As well as hearing typical electrophonic sounds (sizzling, crackling and bangs or pops) at least three people felt something, like a pressure on the chest. All observed effects were simultaneous with the fireball sighting. It is remarkable that none of the normal sonic effects following later were reported, perhaps because the fireball disappeared well out over the Pacific Ocean.

On 1994 February 1 at 22.38 UT a mag -25 fireball entered the atmosphere near Kosrae (Kusaie), easternmost of the Caroline Islands in Micronesia. It was detected by IR and visible light sensors on six different satellites (anon. 1994) and witnessed by two fishermen 300 km away. E. Tagliaferri (1994), a USAF science consultant, reported that only one of the fishermen heard the sounds the fireball made, and turned to see it. The fisherman, Andrew Isaac, heard a "shooshing" sound which made him turn around and see the fireball, which exploded at an estimated altitude of 20 km.

From this and other published reports (e.g. Beatty 1994) it appears that the USAF has satellite information on all bright fireball events with very accurate timing. If it is available, such information should be invaluable for correlation with ELF/VLF electromagnetic records.

Attempts to record VLF radio signals from meteors have been reported by Drobnock (1992) with little success. He claims that there was a "hiccup" in the background noise coincident with the passage of a first magnitude meteor which passed through the zenith. No explanation was given by him.

Beech, et al., (1995) dismiss Drobnock's claim, but, motivated by it, they went on to achieve the second-ever detection of an ELF/VLF EM signal from a bright (mag -10) meteor fireball (the first was published by Watanabe, et al., 1988). Beech and his associates calculated the electric field strength at the antenna to be greater than or equal to 2,000 volts per metre. Broad-band noise of this amplitude could have been heard had a suitable transducing medium been present. Laboratory studies have shown that field strengths as low as 160 volts per metre at a single frequency can produce audible sounds if the transducer is very close to the observer (Keay 1980b).

A negative result was obtained by Maley (1993) in attempts to record ELF radio signals from the reentry of a Shuttle on flight STS-51 on 1993 September 22 at 2.42 am CDT. From the observation point the shuttle passed at a maximum elevation of 23 degrees and its altitude was approximately 40 miles (64 km). It produced an orange-yellow trail estimated to be of magnitude -2 which extended up to 120 degrees in azimuth. It seems likely that the shuttle's altitude/speed profile did not bring it below the transition altitude at which the wake could become turbulent while it was still ionised.

An earlier negative result was cited by Ol'Khovatov (1993) who has apparently confused Shuttle reentry reports. Flight STS-51 (see Maley 1993) did not take place in 1984 and could not have been reported in a 1979 reference. Ol'Khovatov mistakenly attributes the mechanism of the fireball wake generation of ELF radio waves to Bronshten (1983) and disputes his analysis.

A new report by Hall (1992) is difficult to reconcile with the ELF electromagnetic energy transduction to acoustic energy model in the case of auroral sounds. Witnesses to an intense red auroral display reported that "The sound seemed to be associated with bursts of activity because we were often alerted to a new display behind us by the noise." and "I have no doubt the sound came from the aurora since it was directonal." This implies that the necessary transducing medium is associated with the aurora rather than the observer, which seems highly unlikely. A comprehensive review of auroral audibility was published by Silverman and Tuan (1973) and a summary of C A Chant's extensive investigations into the problem has been published more recently by Keay (1990).

At Griffith University in Queensland, O'Keefe and Thiel (1991) have recorded ELF em radiation from large rock blasts in quarries. This is the latest addition to an extensive literature relating ELF/VLF emissions with earthquakes. In the large Los Angeles quake in January 1994 it was reported in TV interviews with zoo staff that animals at the San Diego Zoo became unusually upset just before the event. Similar effects have been noted from some electrophonic meteor fireballs, for example by Moore (1988).

The most recent development emerged at the Small Bodies conference in Mariehamn, Aland (1994 August 8-12) where an abstract submitted by Zhuang and He revealed that Comet De Cheseaux in 1743, the so-called six-tailed comet, at mag -7 one of the brightest on record, produced sounds when it appeared according to official records of the Ching dynasty. They suggest that this may have been due to some of the particles of the comet tail interacting with the geomagnetosphere, likening the mechanism to the production of sound by aurorae.

Recent Theoretical and Modelling Studies

Keay (1992) examined the flight parameters of thirty fireballs for which light-curves are available. From the flight parameters the heights of onset of turbulent continuum flow could be computed using ReVelle's criterion (1979). This was found to be realistic for the Pribram event, as a test case, because Ceplecha gathered many electrophonic sound reports from it. The paper verified Astapovich's earlier empirical conclusion that a fireball should last more than three seconds for it to produce sustained electrophonic sounds.

It must here be mentioned that Keay's 1992 paper contained an error: Bronshten's (1983) calculations indicated that the bolide taken as his example could produce 2.5 x 10^3 kilowatts of radiated electromagnetic power available for transduction into sound - not several kilowatts, as stated in the 1992 paper. It should have stated several megawatts.

Keay and Ceplecha (1994) have calculated the chance of hearing an electrophonic fireball, utilising records obtained in Czechoslovakia (Pribram event) and Oregon and supported by a theoretical model. This was developed from Ceplecha's fireball model modified to incorporate ReVelle's turbulence criterion as used by Keay to determine whether a fireball can produce the EM radiation necessary for electrophonic effects.

These calculations indicated that a person spending all of the nighttime hours outdoors could expect to hear an electrophonic fireball once in a lifetime. This assumes that the person is average: someone with guaranteed maximal sensitivity to electrophonic sounds might expect to hear twenty times that number for the same outdoor exposure.

Further investigations are under way to explore whether the type of electrophonic sound produced by a large fireball may relate to its composition. It appears that the modelling of electrophonic fireballs is now quite good: for example, witnesses reported that the 1978 mag -16 New South Wales fireball produced electrophonic sounds for more than ten seconds. The best-fit model shown in Fig. 1 indicates that the fireball penetrated below the computed turbulent-flow transition altitude for more than fifteeen seconds of its shallow-trajectory flight in the atmosphere.

Calculations based on Ceplecha's model indicate that the duration of electrophonic effects is very dependent on the angle of entry in accordance with observations. This shown in Fig. 2, which was computed for a fireball of cometary composition. The dependence on meteoroid composition is much greater, as indicated in Fig. 3, which is calculated for each of the major compositional groups, assuming the most likely entry angle of 50 degrees to the zenith.

Although the duration of the sounds is composition dependent,

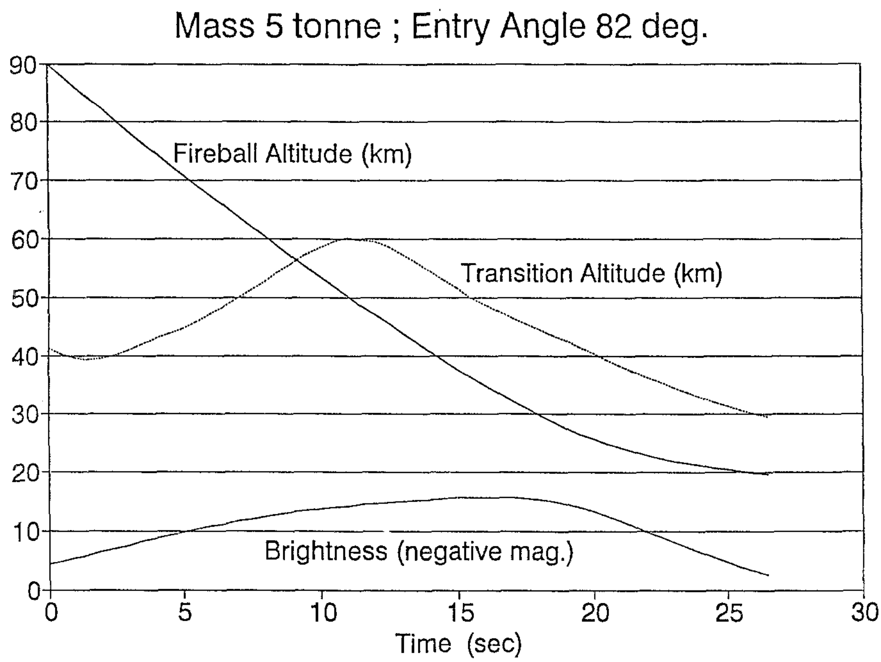

Fig. 1. Best-fit model for the April 1978 New South Wales Fireball, matching its observed duration and brightness most closely. The fireball was below the computed turbulent-flow transition altitude for more than fifteen seconds.

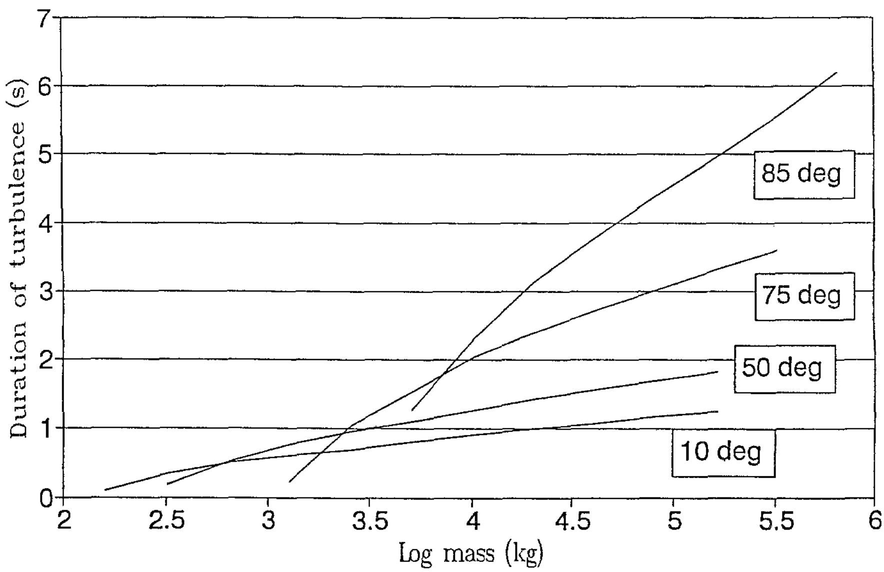

Fig. 2. The duration of turbulent conditions in the plasma trail of a fireball is strongly dependent on the fireball entry mass and the angle of entry, shallow trajectories producing the greatest duration in most cases. These curves apply to a fireball of cometary composition having a bulk density of 0.75 grams per cubic centimetre.

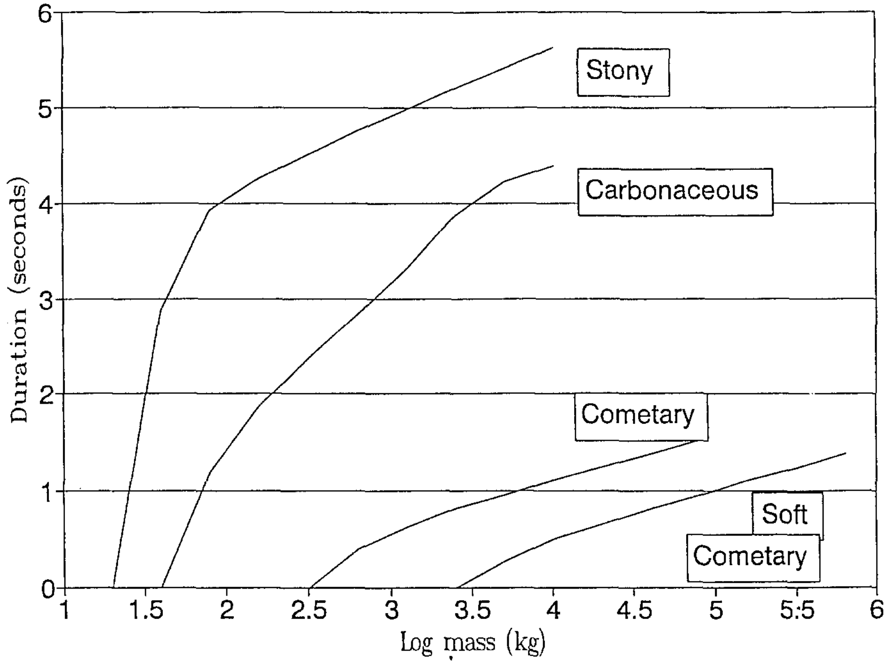

Fig. 3. For the most likely entry angle (50 degrees to the vertical) the duration of trail turbulence is strongly dependent on the density of the meteoroid, which is in turn dependent on its composition.

the nature of the sounds may conceivably be an even better discriminant. As mentioned above, Keay (1993b) grouped the descriptions of the sounds into three classes: Smooth, Staccato and Sharp. The latter arise from explosive events in an otherwise sub-electrophonic fireball. A series of fragmentations of a continuously electrophonic fireball may explain the intermediate (Staccato) class of sound.

Concluding Comments

The increasing scope of phenomena involving the transduction of ELF/VLF EM radiation into audible sound demands the use of a collective term for this new field of study. It is proposed that it should be known as geophysical electrophonics.

In conversations with historians and classical scholars it is becoming evident that geophysical electrophonics can provide a physical explanation for many episodes hitherto assumed to be supernatural, such as celestial noises accompanying tongues of fire and similar manifestations, described in many scriptures, scrolls and ancient writings (a very good example is Acts 2:2 in the Christian Bible).

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