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Do meteors radiate very-low-frequency radio emissions?

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Extended Abstract

The plasma produced when a meteoroid enters the Earth's atmosphere – a meteor – is a complex, dynamic, and rapidly-evolving phenomenon. Meteors are commonly observed through their optical emissions, but also through scattering of radar waves transmitted from the ground, typically in high frequency (HF, 3–30 MHz) through ultra-high-frequency (UHF, 0.3–3 GHz) bands. More recently, it has been demonstrated that meteors in fact radiate HF/VHF emissions naturally [*Obenberger et al.*, 2014, 2016, 2020]. These emissions open questions into the physical mechanism that produces this radiation, which will likely lead to insights into the development and evolution of meteor plasma.

The possibility that meteors radiate in the very-low-frequency band (3–30 kHz) has been investigated since the late 1950s. Early work associated meteors with audio signatures, supposedly produced through electrophonics in a nearby conductor [*Astapovich*, 1958; *Lamar and Romig*, 1964; *Keay*, 1980]. More recent work has presented direct measurements of VLF signals associated with meteors [*Beech et al.*, 1995; *Price and Blum*, 1998]. If real, just like the HF/VHF emissions, such VLF emissions from meteors would raise valuable questions about the mechanism of emission from the meteor plasma. However, there exists no consensus as to whether the observed VLF signatures can be causally connected to the observed meteors. Using a modern VLF receiver and a sophisticated network of meteor cameras, *Sung et al.* [2020] studied two years of meteors and their associated VLF emissions, but found no evidence of a unique meteor-associated VLF signal.

In this paper, we present the development and first results from a new VLF and meteor camera network in pursuit of these elusive emissions. Three all-sky meteor cameras were installed in Colorado in the summer of 2020, along with two VLF receivers. Two more cameras are planned to be deployed in early 2021. The cameras use the University of Western Ontario's automated meteor detection software to extract meteor events. Broadband, 0.3–50 kHz VLF data is recorded continuously at all sites and then post-processed to extract segments of data during meteor observations. Since July 2020, hundreds of meteor observations have been collected and analyzed.

To search for VLF signatures of meteors, we apply a variety of signal processing techniques to the data in order to separate other natural and anthropogenic signals from potential meteor signatures. Of particular interest, we apply a "Sparse Separation" technique (outlined in *Strauss* [2013]) to extract Fourier components (e.g. power line harmonics and VLF transmitter signals) and Wavelet components (e.g. lightning-generated sferics). The remaining signal, extended in both time and frequency and hence "noise-like", provides an avenue to search for unique signatures. We compare each of these data components before, during, and after meteor observation times to identify enhancements in the temporal or spectral signatures. Despite this thorough analysis, to date no clear evidence of VLF emissions associated with our meteor observations has been found. Nonetheless, we will continue to collect and analyze data with the goal of providing the most concrete evidence, to date, either for or against VLF emissions from meteors.

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