SAND2023-01515C

The 2020 Earthgrazer: Infrasonic Detection of a Rare Meteor Event

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Abstract #: 1060

1. Introduction

- Well-documented observations of earthgrazing meteoroids are exceptionally rare [1]. These objects are unique in that they enter the Earth's atmosphere at an extremely shallow angle relative to the horizon.
- While interacting with the denser regions of the atmosphere, an earthgrazing meteoroid might undergo ablation and produce a luminous path that could span as much as several hundreds of kilometers [2]. Earthgrazers generally do not penetrate deep into the atmosphere; documented cases had their minimum altitude between ~70 km and ~100 km [1].
- During their passage through the atmosphere, sufficiently large and fast meteoroids produce shockwaves that can decay to very low frequency acoustic waves, also known as infrasound [3]. Theoretically, earthgrazers falling within that category should also generate infrasound. However, documented infrasound detections of earthgrazers are nearly non-existent.
- Here we report an infrasound detection of a rare earthgrazing fireball.

2. Earthgrazer over Europe

- A rare horizon-to-horizon earthgrazer event occurred over northern Europe on 22 September 2020 at 03:53:40 UTC, capturing attention of many eyewitnesses and numerous ground-based cameras aimed at the skies (**Fig. 1**) [4].
- As per the analysis released by the Global Meteor Network [6], the luminous path of the earthgrazing fireball started over Germany and ended over the UK (**Fig. 2**), at the altitude of 101 km and 107 km, respectively.
- The point of the closest approach was at ~90 km. The object's velocity upon the entry was ~34 km/s, and only slightly less, ~30 km/s, when it exited [4,5].

Figure 1: All-sky camera image of the earthgrazer. Image credit: Cees Bassa [5].

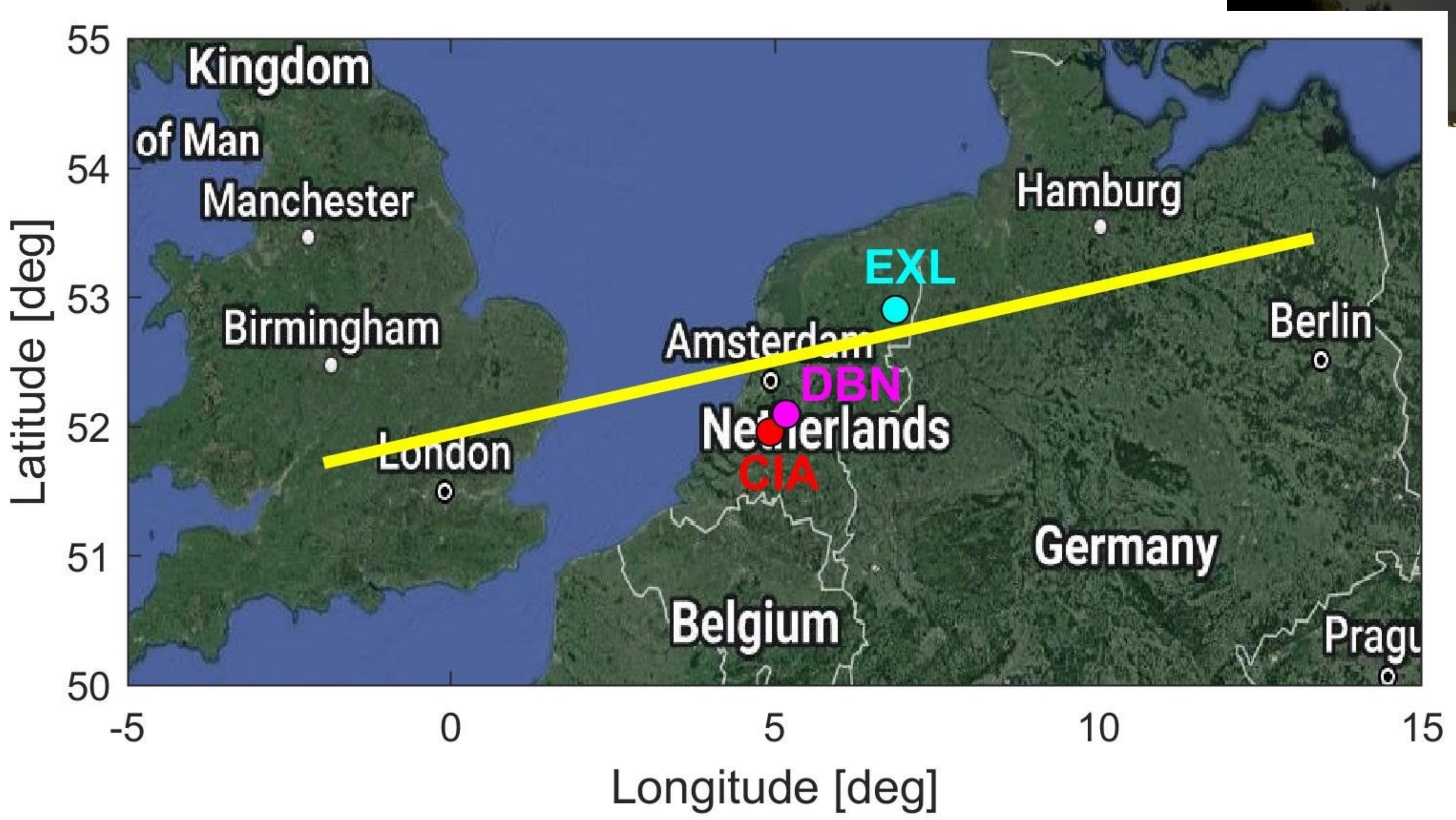

Figure 2: Ground track of the earthgrazing fireball. The entry point was over Germany and the exit point over the UK. Infrasound stations that detected the event are also shown.

3. Infrasound detection

- Despite its high-altitude and apparently silent (to humans) passage, the earthgrazer was detected by infrasound sensors of the Royal Netherlands Meteorological Institute (KNMI) network [6] several minutes after it had entered the atmosphere.

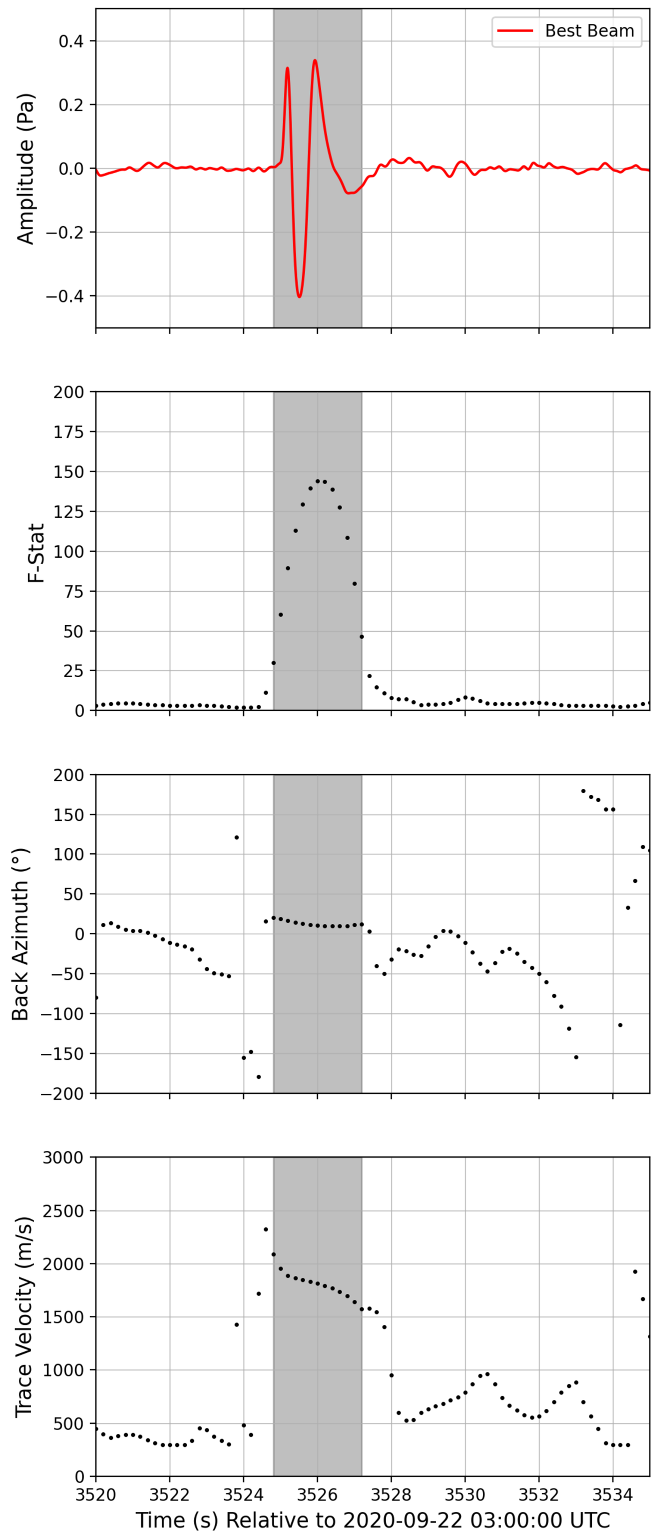

Figure 3: Filtered time series [0.4 – 4.1 Hz] recorded by the EXL array. The maximum and peak-to-peak amplitude is 0.12 Pa and 0.26 Pa, respectively. Also are included the F-stat, back azimuth and trace velocity plots.

- Three infrasound arrays of the KNMI network detected the signal: EXL, DBN, and CIA (**Fig. 2**). The signal was first detected by the EXL array at 03:58:44 UTC, a few minutes after the onset of the luminous path (**Fig. 3**). The infrasound signatures at all three arrays exhibited an N-wave appearance, diagnostic of a ballistic shock [6]. The frequency content was below 5 Hz. The spectrogram at Channel 2 (EXL) is plotted in **Fig. 4**.
- The signal trace velocity at all stations was high, indicative of a direct arrival from a high-altitude shock produced by the cylindrical line source [6]. At EXL, which was in the close proximity to the earthgrazer trail, the apparent signal arrival was nearly vertical, consistent with our conclusion that the signal was ballistically generated. We hypothesize that the signal detected at EXL came from a different part of the trail compared to that detected by DBN and CIA. Further analyses are underway to test this assertion.
- The average dominant signal period across the three stations was 1.43 ± 0.20 seconds. Using the AFTAC energy relations adapted to bolides [7], the energy release was estimated at 18 ± 8 tons of TNT equivalent across the three stations. Our very preliminary estimate places the meteoroid diameter at ~1 m. Assuming the chondritic composition, the mass estimate is ~1.4 metric tons.

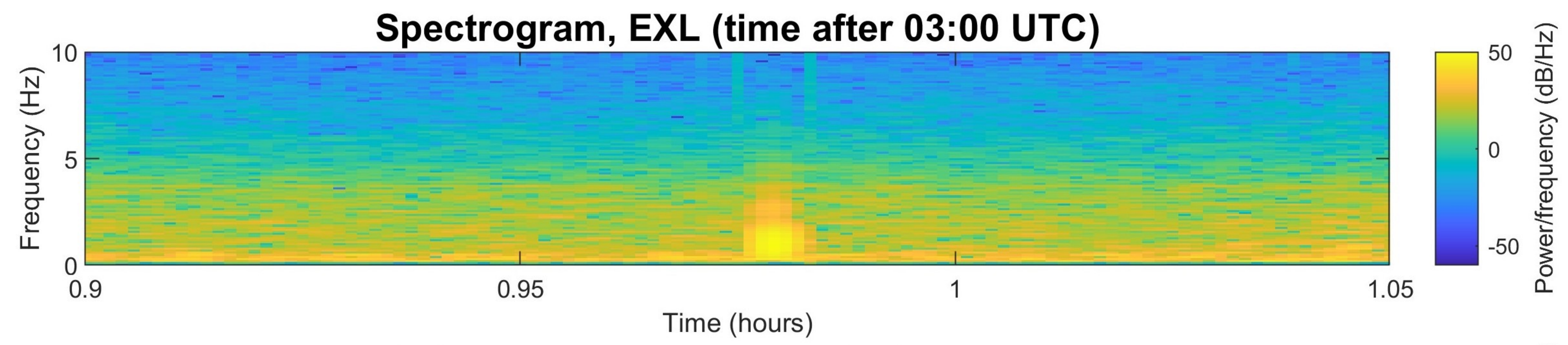

Figure 4: Spectrogram at channel 2 of the EXL array.

4. Summary

- The extremely shallow entry angle of the fireball enabled the infrasound wave to readily propagate downward, thus assuming a direct path to the receiver.
- This unique earthgrazing fireball event provides valuable constraints for infrasound detection and characterization of high-altitude meteor events [4,8].

References

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