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Infrasound observations of the September 22, 2020 earthgrazing fireball

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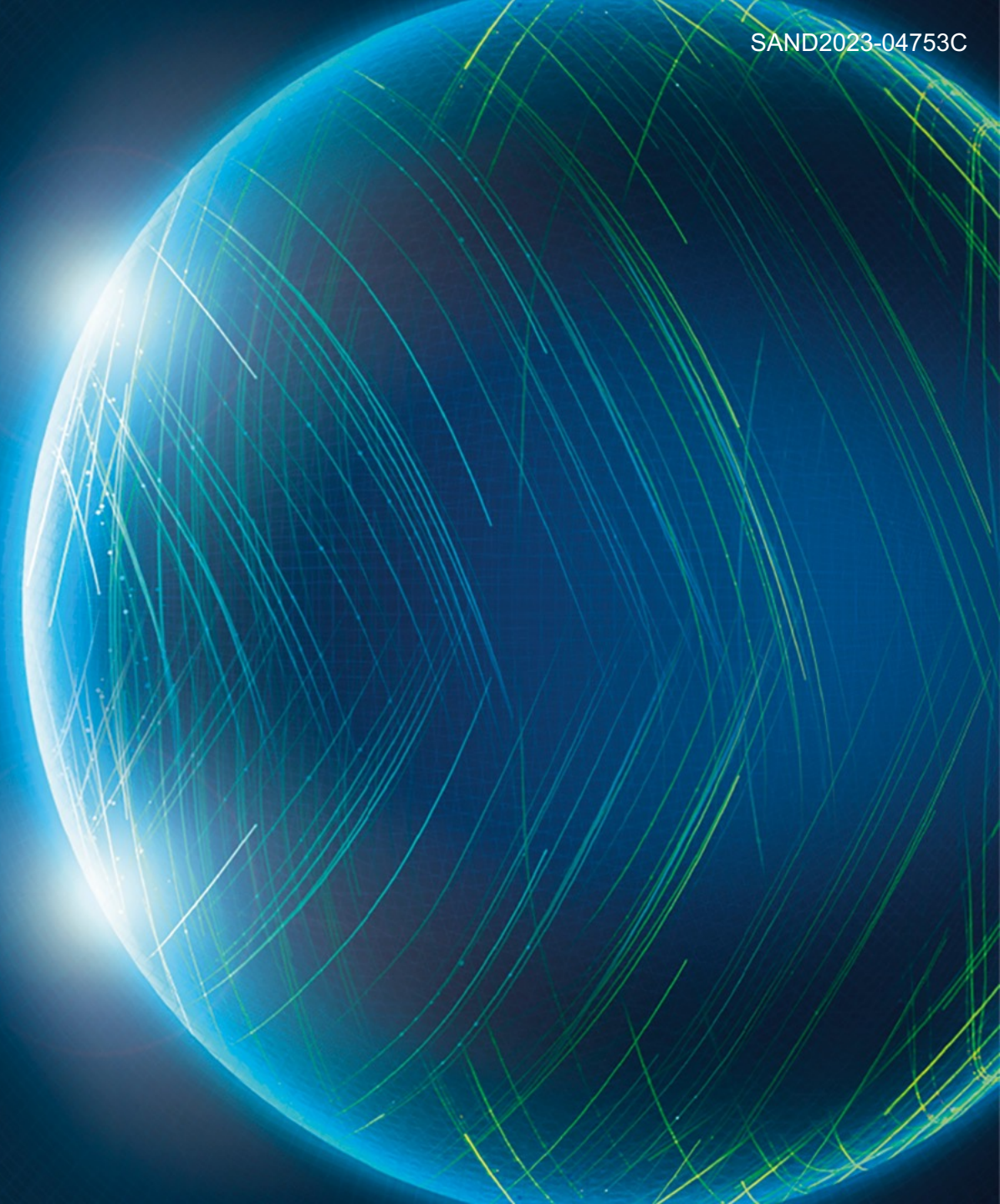


Introduction: Earthgrazers

- Well-documented observations of earthgrazing meteoroids are exceptionally rare [1].

Frederic Edwin Church, The Meteor of 1860 (this was an Earth-grazing meteor procession)

- 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 [1-4].
- Earthgrazers generally do not penetrate deep into the atmosphere; documented cases had their minimum altitude between ~70 km and ~100 km [3].

Introduction: Infrasound

Image credit: NASA

- During their passage through the atmosphere, sufficiently large and fast meteoroids produce shockwaves that decay to very low frequency acoustic waves, also known as infrasound [2,5].
- Theoretically, earthgrazers falling within that category should also generate infrasound [5]. However, documented infrasound detections of earthgrazers are nearly non-existent.
- Here we report an infrasound detection of a rare earthgrazing fireball.

Earthgrazer over Europe

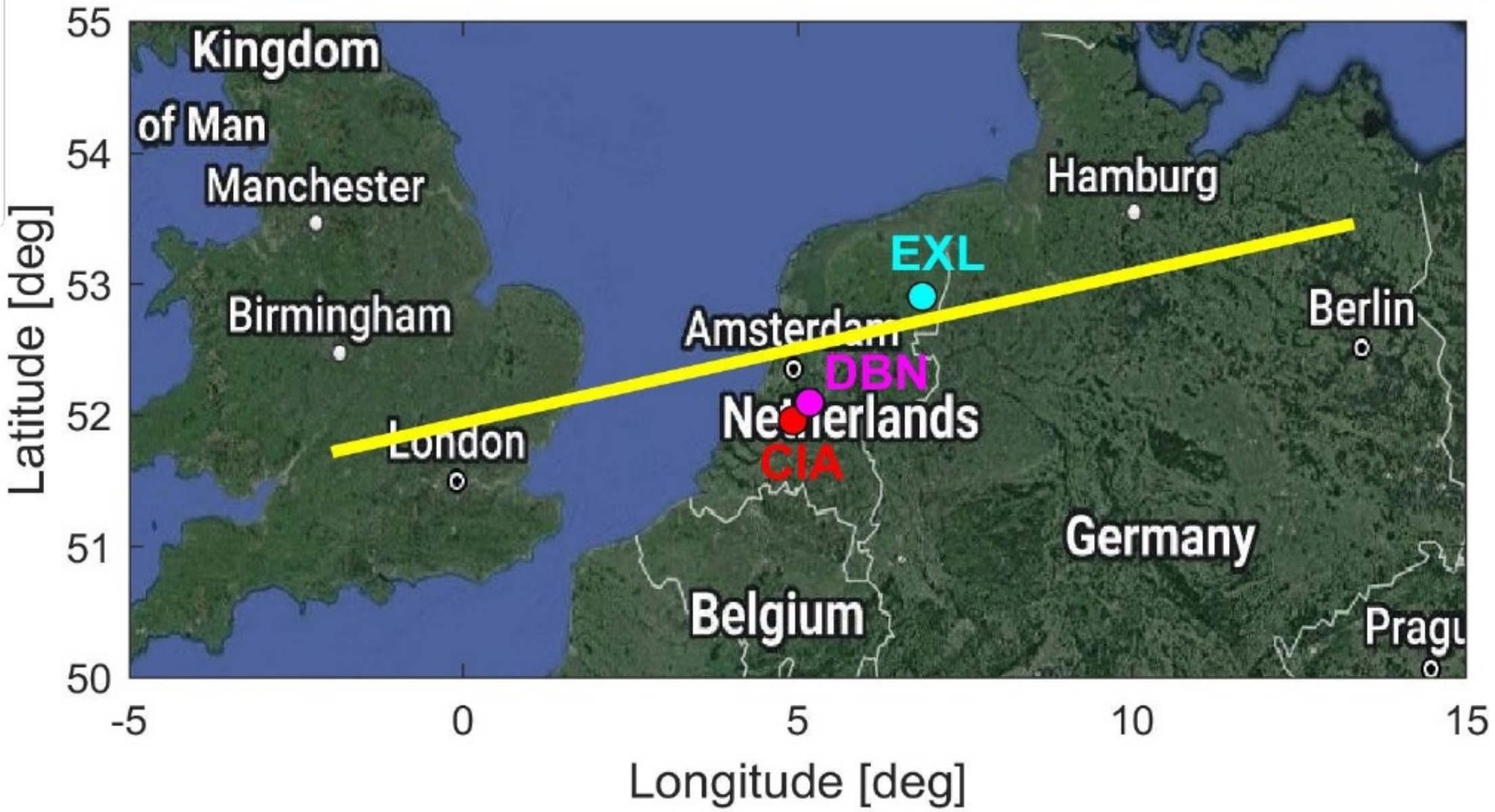
- A rare horizon-to-horizon earthgrazer event occurred over northern Europe on 22 September 2020 at 03:53:40 UTC [6].
- The luminous path of the earthgrazing fireball started over Germany and ended over the UK, at the altitude of 101 km and 107 km, respectively [6].
- The point of the closest approach 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 [6].

All-sky camera image of the earthgrazer.
Image credit: Cees Bassa.

Earthgrazer over Europe

Credit: Global Meteor Network

Ground track



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 [7].
- Three infrasound arrays of the KNMI network detected the signal: EXL, DBN, and CIA.

- The signal was first detected by the EXL array at 03:58:44 UTC, a few minutes after the onset of the luminous path. The infrasound signatures at all three arrays exhibited an N-wave appearance, diagnostic of a ballistic shock [5].
- 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 [5].

Results

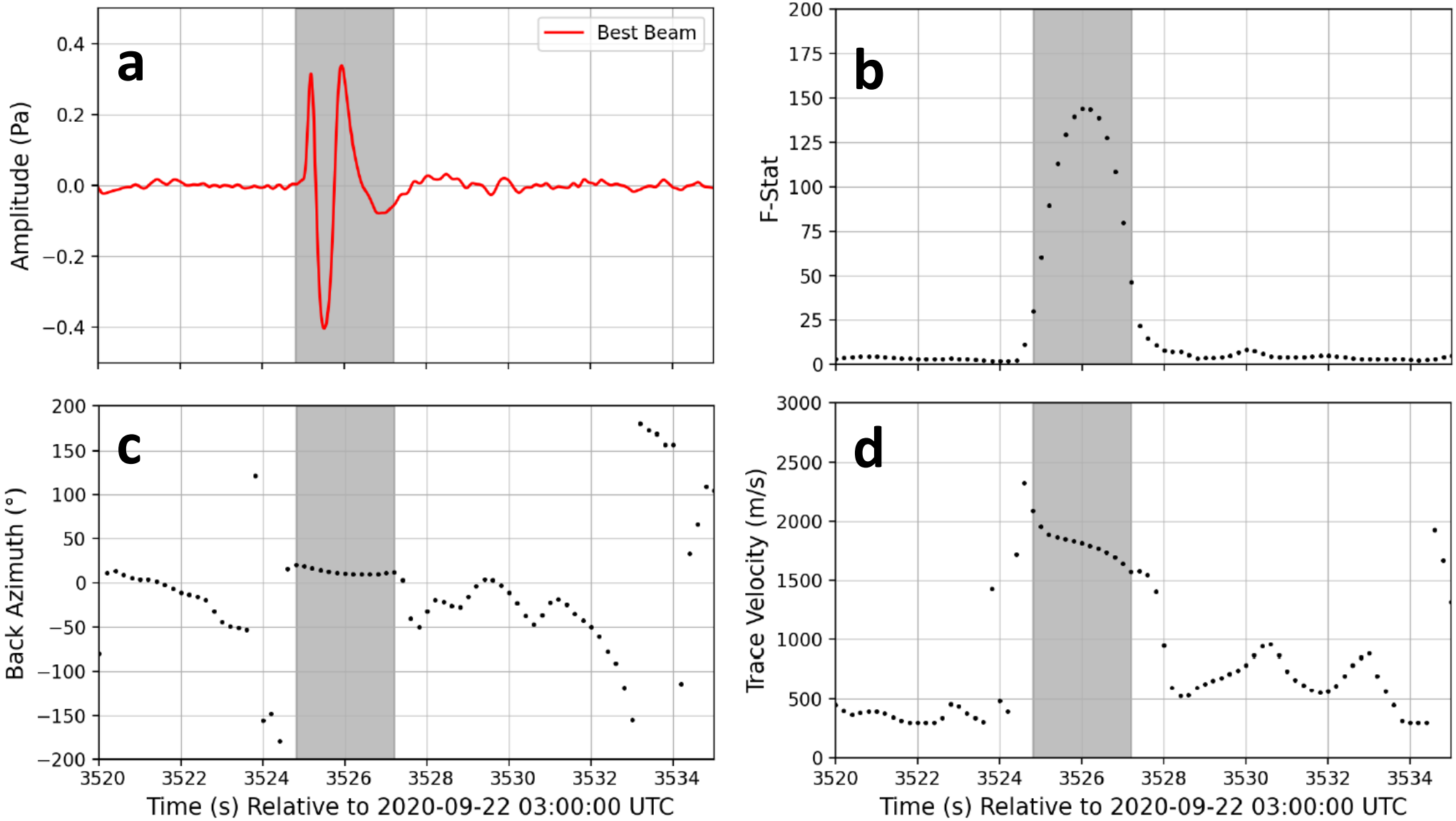
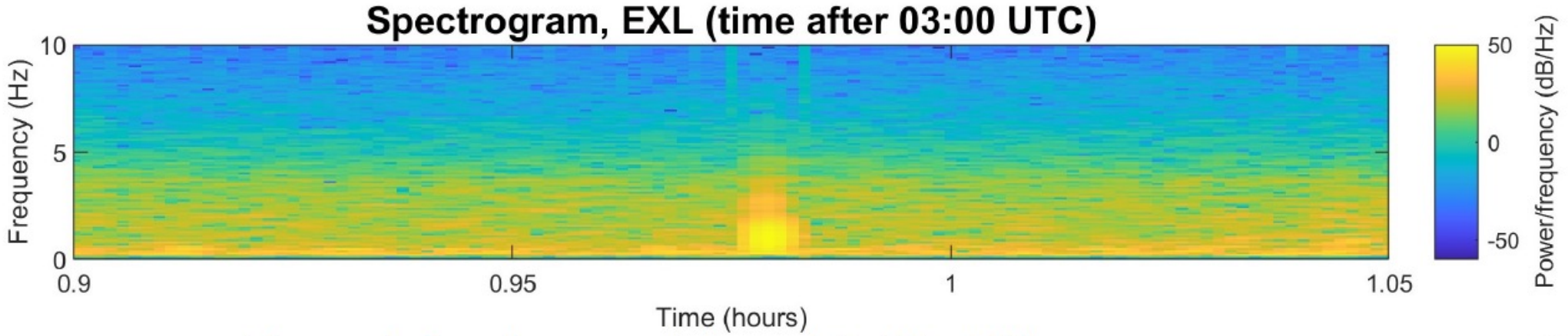


Figure 3: Filtered time series [0.4 – 4.1 Hz] recorded by the EXL array. The maximum and peak-to-peak amplitude is 0.12 Pa and 0.26 Pa, respectively. Also are included the F-stat, back azimuth and trace velocity plots.

Results cont'd



- We hypothesize that the signal detected at EXL came from a different part of the trail compared to that detected by DBN and CIA.
- The average dominant signal period across the three stations was 1.43 ± 0.20 seconds.
- Using the AFTAC energy relations adapted to bolides [8], the energy release was estimated at 18 ± 8 tons of TNT equivalent across the three stations.
- Our preliminary estimate places the meteoroid diameter at ~1 m. Assuming the chondritic composition, the mass estimate is ~1.4 metric tons.

Summary

All-sky camera image of the earthgrazer.
Image credit: Cees Bassa.

- 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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[3] Shober P. M. et al. (2020) Astron. J., 159:191.
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[6] Vida D. et al. (2020) Global Meteor Network.
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[8] ReVelle, D. O. (1997). Annals of the New York Academy of Sciences, 822(1), 284-302.

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