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# PEAK-BRIGHTNESS LOCALIZATION OF THE CNEOS 2014-01-08 (IM1) FIREBALL

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## ABSTRACT

In a recent preprint, Fernando et al. (2024) used public data from infrasound stations to constrain the localization of the fireball of the CNEOS 2014-01-08 (IM1) bolide. The analysis inferred a 90%-confidence ellipse with semi-minor and semi-major axes of 186 and 388 km, respectively. This large error ellipse includes the much better localization box derived by sensors aboard U.S. Government satellites which detected the fireball light. At the fireball's peak brightness, the CNEOS localization box documented by NASA/JPL measures 11.112 km on a side and is centered on a latitude of 1.3°S and a longitude of 147.6°E. Here, we point out that the recent expedition to retrieve materials from IM1's site (Loeb et al. 2024a,b,c) surveyed a region of tens of km around the CNEOS box center, and was not dictated by the data studied by Fernando et al. (2024) because of its larger uncertainties.

## 1. INTRODUCTION

On January 8, 2014, US government satellites detected the light from a fireball of a meteor, labeled CNEOS 2014-01-08 (hereafter abbreviated as IM1), that was moving significantly faster than the escape speed from the solar system (Siraj & Loeb 2022). The location, velocity and radiated energy of the meteor were documented in the official website[1] of the Center for Near Earth Object Studies (CNEOS) fireball catalog, compiled by NASA/JPL. The interstellar origin of IM1's velocity vector was double-checked and confirmed at the 99.999% confidence level in an official letter dated March 1, 2022 from the US Space Command to NASA.[2]

The lightcurve of the fireball was included in the CNEOS database,[3] with a document narrative explaining that the detection was made by "sensors aboard U.S. Government satellites", which were triggered by a "flash signature of a large meteoroid entry into the atmosphere" at a latitude of 1.2°S and a longitude of 147.1°E. The peak brightness of the fireball was reported in the CNEOS catalog table at a latitude of 1.3°S, a longitude of 147.6°E and an altitude of 18.7 km. The vector connecting the atmospheric entry flash and the fireball's peak brightness agrees with the measured direction of motion of the bolide after its atmospheric entry, as documented in the CNEOS catalog table.

The fireball lightcurve shows three prominent, equally-separated flares, with the peak brightness associated with the last flare, ending about 0.3 s after the beginning of the first prominent flare. The reported localization and altitude in the CNEOS catalog table correspond to the brightest third flare.

## 2. PEAK-BRIGHTNESS LOCALIZATION

The peak-brightness location of IM1 was defined in the CNEOS fireball catalog to within a tenth of a degree precision in latitude and longitude, corresponding to 11.112 km on the Pacific Ocean surface, centered about 90 km away from Manus Island in Papua New Guinea. Better localization was not meaningful since the fireball's speed of 44.8 km $s^{-1}$ and direction of motion at a 31° angle relative to the ocean surface, implied that the bolide traveled across a path of 13.44 km over the 0.3 s duration of its prominent flares.

On June 14-28, 2023, an expedition was conducted to retrieve meteoritic materials from IM1's site (Loeb et al. 2024a,b,c). The surveyed region centered on the CNEOS localization box and included 26 runs across a region extending out to several tens of km away from the box center, as shown in Figure 2 in Loeb et al. (2024a).

In a new preprint, Fernando et al. (2024) analyzed seismic and acoustic data from a wide region around IM'1 impact site. This data is independent from the data reported by the U.S. Government satellite sensors. Based on infrasound data, Fernando et al. (2024) inferred a 90%-confidence localization ellipse with semi-minor and semi-major

[1] https://cneos.jpl.nasa.gov/fireballs/
[2] https://lweb.cfa.harvard.edu/~loeb/DoD.pdf
[3] https://cneos.jpl.nasa.gov/fireballs/lc/bolide.2014.008.170534.pdf

axes of 186 and 388 km, respectively, and an area of 227,000 km$^2$, which includes the CNEOS localization box but is centered at a distance of $\sim$ 170 km from it. Whereas this result is consistent with the much better CNEOS localization, Fernando et al. (2024) suggest that the expedition might have been misguided in surveying the region identified by the U.S. Government satellites based on the detected fireball light.

## 3. DISCUSSION

Siraj & Loeb (2023) considered seismometer data from Manus Island (AU.MANU) to test consistency with the CNEOS localization box, altitude and timing. However, the time delay associated with any acoustic or seismic signal detected by a single station, can only constrain within uncertainties the distance of the fireball from that station, implying a fireball location within a circular band of some uncertainty-width in all possible directions around the station. Consequently, the region surveyed by the expedition (Figure 2 in Loeb et al. (2024a)) could not have been defined by this analysis, as suggested by Fernando et al. (2024). Actual localization requires multiple stations as used by Fernando et al. (2024), but that analysis resulted in a large 90%-confidence ellipse - consistent with the better localization box derived by U.S. Government satellites and documented by NASA/JPL in the CNEOS catalog.

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