PROBABLY NOT ALIENS: SEISMIC DATA ANALYSIS FROM THE 2014 'INTERSTELLAR METEOR'

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Introduction: One tantalising implication of the discovery of 1I/'Oumuamua in 2017[1] was that objects of interstellar origin occasionally collide with the Earth. The rate and size of such impacts is almost entirely unconstrained[2], however detecting an interstellar meteoroid entering the atmosphere would be of immense scientific value.

Aside from enabling study of the object's trajectory, shape, and composition, bolide detection would allow for potential localisation of fallen material. This may take the form of the meteorite impactor itself, or its strewn field. Such a discovery would open the door to the first study of extrasolar material via the same sorts of precision analytical procedures which are commonly applied to Solar System meteorites.

Numerous techniques exist for localising the fall locations of meteorites using methods such as infrasonics, seismics, and photometery[3]. However, these methods generally require multiple independent sensors, and even then are not without their challenges. Calibration of measurements against meteoroids with independently determined characteristics standards is almost impossible[4], and over most of the Earth's surface sensor coverage is very limited, leading to large error ellipses. Even if a fall location can be identified, only a very small fraction of a bolide's initial mass is expected to make it to the surface.

For a potential interstellar bolide, the challenges are likely to prove even greater. Tracking and localisation techniques are unlikely to have been tested for the much higher entry velocities of these meteoroids[5], which also likely result in wider fall regions due to atmospheric breakup at higher altitude.

The 2014 'Interstellar meteor': On January 8, 2014, a small meteoroid fireball occurred off the coast of Papua New Guinea. The unusually high reported velocity of this meteoroid, has led[6] to the (disputed[7]) suggestion that it was on an interstellar trajectory when it entered the Earth's atmosphere, though the velocity may have been substantially over-estimated[5].

More recently, it has been purported that the acoustic signal from the bolide was detected on seismic stations in the region, and that exact identification of the fireball location[8] is possible.

A 2023 oceanographic expedition to this area has claimed recovery of material from the strewn field, in the form of metallic spherules[9]. It has also been suggested that the spherules' composition is indicative of an artificial (i.e. extraterrestrial) origin[10]. We note that this interpretation has been widely questioned, and by no means represents the scientific consensus[11]. Settling this controversy would require conclusive recovery of fallen material, in turn requiring the fireball location to be very precisely identified.

Aim: The aim of this work is to perform an independent analysis of the seismic and acoustic data used and to determine whether (1) this could conceivably be from a fireball and (2) whether if so, the derived localisation constraints are valid and what implications this has for the recovery of strewn field material from the bolide.

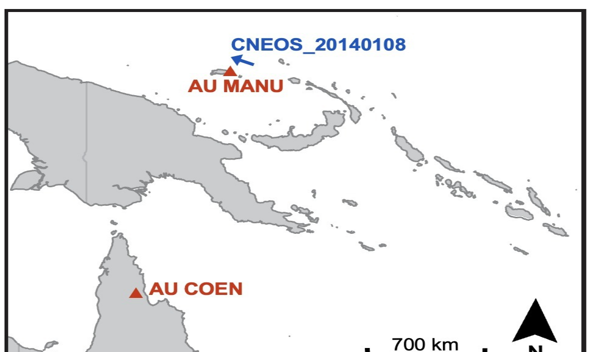

Fig. 1: Seismometer and source locations; map centred on eastern New Guinea with Queensland visible at bottom.

Data: In this work, we analyse seismic data recorded by Geoscience Australia's Passive Seismic Network stations at Manus Island, Papua New Guinea (AU.MANU, Figure 1) and Coen, Queensland, Australia (AU.COEN).

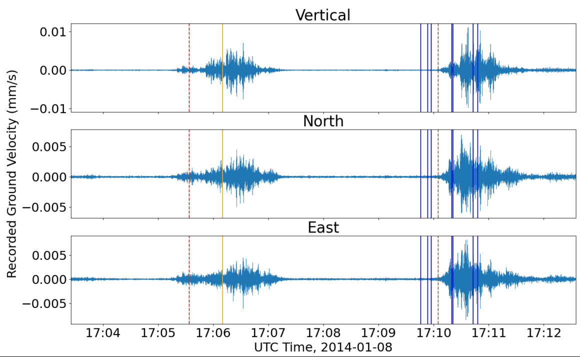

Fig. 2: Three-component seismogram data from Manus Island. Dashed red line: fireball origin time. Dashed brown line: previously reported seismic arrival[7] Solid lines: TauP[12] - calculated arrival times for an earthquake in the Kuril Islands (orange – S, blue – SS).

Initial results: Processed data from the seismometer at Manus Island is shown in Fig. 2. This signal is not unusual compared to other events occurring in the region at that time in duration, amplitude, or waveform shape.

The vast majority of these are presumably tectonic, which is unsurprising given the position of Manus Island on the Pacific Ring of Fire; and their seismic signals are highly likely to overprint on each other – as an example, we show calculated arrival times for an Mb 5.0 earthquake in the Kuril Islands which occurred at 16:50 UTC (ISC Bulletin ID 603942758).

The precision with which the first arrival (dashed brown line) can be picked is on the order of several seconds, which will yield large errors in single-station localisation regardless of the source.

Discussion: The localisation constraints based on the signal from AU.COEN are likely spurious. No signal within 30s of the reported time (18:23 UTC)[7] is apparent once the instrument response has been properly removed. Even if such a signal were recovered, any localisation would need to account for the very steep topographic variation (up to 4000m) over the propagation path, which would affect infrasound waves considerably.

It is physically conceivable that infrasound could propagate the ~80km from the reported fireball location to Manus Island. However, for a randomly selected seismic signal on 2014-01-08 at AU.MANU, it is overwhelmingly more likely to be tectonic in origin and hence the terrestrial origin hypothesis must be thoroughly excluded.

The reported AU.MANU signal at is unremarkable compared to other tectonic signals recorded on the same day, and is highly likely contaminated by regional-to-teleseismic arrivals. This means that envelope fitting or matching to a photometric light-curve is likely to be very dubious.

The signal does not present any clear evidence of being infrasonic in nature, though it does lack low-frequency energy and is potentially polarised in a roughly corresponding direction.

Conclusions: Accordingly, we conclude that the signal at AU.MANU is possibly infrasound arrival from bolide in question, but there is no clear evidence for it being so. It is likely contaminated by seismic arrivals from tectonic events nearby, modifying any underlying signal. Furthermore, the accuracy with which the first arrival can be picked has been significantly overstated. The reported signal at AU.COEN is entirely spurious, in our analysis.

As such, localisation of the strewn field is reliant on a single station and a signal with no clear phases. Therefore, we consider it to be at best highly overstated and at worst entirely erroneous. Poor localisation implies that any material recovered is far less likely to be from the meteor, let alone of interstellar or even extraterrestrial origin.

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Fireball parameters are taken from the Jet Propulsion Laboratory at the California Institute of Technology's Center for Near-Earth Object Studies database, which is also available freely online.

References:

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