THE CHALLENGES OF RECOVERING INTERSTELLAR METEORITES. S. J. Desch[1], A. P. Jackson[1] and H. E. Hartnett[1], [1]School of Earth & Space Exploration, Arizona State University, PO Box 871404, Tempe AZ 85287 steve.desch@asu.edu.

Introduction: The bolide CNEOS-2014-01-08 is reported [1] to have disrupted at 1.2ºS, 147.6ºE (north of Papua New Guinea) at altitude 18.7 km, while traveling at V=44.8 km/s. If the reported velocity is correct, it would be interstellar in origin [2]. It has been proposed to collect fragments of it from the seafloor using a magnetic sled [3], without a recognition of how little material would survive entry. Although likely an iron meteorite, we calculate <10 g, and probably much less, would have survived entry. Surviving fragments would be spread out over tens of km^2 and would be mixed with and vastly outweighed by many kg of common micrometeorites.

Composition and Mass: At the time of disruption, assuming an air density at 18.7 km ρ=0.116 kg m^{-3}, we derive a ram pressure ρV^2=233 MPa, comparable to other estimates (194 MPa [3], 247 MPa [4]). This is within the range of yield strengths Y for rocky bodies (L chondrites Y < 600 MPa) and iron meteorites (Y=300-700 MPa) [5]; [NB: [3] are wrong to report Y=50 MPa for irons]. Given typical strength-yield relations [6], an iron meteoroid is more likely; most rocky meteoroids disrupt at 1-5 MPa [5]. The total optical energy was reported [1] as E_O=3.1 x 10^{10} J, assuming a 6000 K blackbody. This yields the kinetic energy $E=E_O/\tau$, where τ is the luminous efficiency. The calibrations of [7] yield τ=6.9±4.8%, E=0.11±0.08 kt and mass 450±310 kg, but this may underestimate τ. The relations of [8] suggest τ=15% and mass 200 kg, and those of [9] suggest τ=5-12% and mass 620-260 kg. Experiments show τ may increase steeply with velocity for irons in particular [10]. We assume the bolide was iron, with mass $M\approx$300 kg, radius ≈20 cm.

Ablation: Almost all of this mass was vaporized in the atmosphere. The surviving mass is [11]:

$$M_f = M \exp\left(-\sigma \left(V^2 - V_f^2\right) / 2\right),$$

where V_f=few km/s and σ is the ablation coefficient for irons. This result is independent of the details of the disruption. For σ=0.005, 0.01, or 0.02 s^2/km^2, $M_f \approx$2 kg, 13 g, or 0.6 mg. Typically σ=0.01 s^2/km^2 is assumed, and fits to meteors find an average 0.014 s^2/km^2 [8]. Due to the relative ease of ablating iron, σ may be higher for iron meteors than rocky ones, by a factor ≈3.5, and values up to 0.07 s^2/km^2 are inferred [12], which would yield **no** surviving mass. We consider it likely that $\sigma > 0.01$ s^2/km^2, and that *at most* about 10 g could survive the ablation process. For typical micrometeorite masses (~0.3 mg), this implies < 3 x 10^4 micrometeorites each hundreds of μm in size.

Challenges to Recovery: The location where the bolide disrupted is uncertain to within about ±10 km [1]. The length of the strewn field is also ~10 km, owing to uncertainties in the fragment size distribution. In addition, assuming Stokes flow to the ocean floor at ~2-3 km depth, fragments 1 mg – 1 g will take 30–0.3 minutes to sink. Given the typical speed of the Equatorial UnderCurrent (EUC), > 1 m/s [13], fragments would be carried eastward varying distances *at least* several km, and probably carried much farther. The search area would be *at least* ~10 km^2.

A magnetic sled can extract magnetic spherules < 1 mm in size from the topmost ~10 cm of the seafloor; [14] extracted 1200 spheres totaling 30 mg from 750 kg of Pacific red clay. Using a similar device, [16] were able to process ~10^7 kg of seafloor sediment per day. It is planned [3] to operate for 10 days, processing process 6 x 10^7 kg of sediment over 0.4 km^2, about 4% of the search area. One would expect recovery of *at most* 400 mg (~10^3 particles) of interstellar material, but >2.4 x 10^6 mg (~ 10^7 particles) of Solar System micrometeorites, plus an even larger amount of terrestrial magnetic particles. [3] offered no plan for identifying extrasolar micrometeoroids among the millions of normal micrometeoroids.

Conclusions: Even with conservative estimates of the ablation coefficient, interstellar micrometeorites from the 2014-01-08 bolide, even if any survived, would be vastly outnumbered by—and likely indistinguishable from—normal micrometeorites. Given the necessarily high velocities of interstellar meteors, only much more fortuitous geometries than this case may allow recovery of interstellar material.

References:

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