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PLANETARY DEFENSE: A METEORITE PERSPECTIVE

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INTRODUCTION

- Following Chelyabinsk [1,2], and programs for impact mitigation [3,4], we have established an ARC/LLNL program to understand (1) the physics of meteorite fall and (2) the characteristics of asteroid surfaces, which inform deflection strategies.
- Meteorites falls suggest a wide variety of atmospheric behavior (Fig. 1).
- Here we review what can be learned about planetary defense from meteorites and meteorite falls.

I. THE MECHANICS OF METEORITE FALLS

- Eye witness observations of meteorite falls can provide insights into meteorite entry, e.g. 20 falls reported in the 1960s produced the following: Explosion 85%, Rumbling 35%, Whistling 45%, Light 55%, Flares 10%, Dust trail 30%. All falls before 1860, a sulfurous smell [5]. Witnesses can also record the amount of dust which provides information on the amount of fragmentation and ablation [6]).
- Light curves, for ~ 20 meteorites [e.g. 7-9], provide quantitative information on the beginning and end of luminous flight, the rate of energy loss, the dynamic and photometric mass, major break-up events, velocity as a function of time, and especially they can be used to test numerical models.
- The fusion crust records quantitative details of the later stages of flight (Fig. 1), namely airflow around the meteorite, orientation, thermal gradients, ablation rates, fragmentation history, orientation [5,10,11].
- Meteorite Fragments from ten craters [12] provide an opportunity to test numerical models because we have two pieces of critical data, the crater and the meteorite (Fig. 2).

II. DETAILS OF FALL AND ASTEROID SURFACES

- Meteorite characterization not only aids in modelling atmospheric behavior, it also has the potential to provide insights into the asteroid surfaces.
- Laboratory Studies of Meteorites enable a large number of relevant measurements.
- Cosmogenic isotope studies can determine preatmospheric mass (Fig. 3) [5].
- An extensive literature database exists for the chemical composition of all classes of meteorite.
- Meteorites of the same chemical class can have very different internal properties that can greatly influence atmospheric behavior (Fig. 4).
- Laser-driven shock experiments to measure temperature dependence of flow stress, phase transition pressure, and tensile (spall) strength for a range of meteorite types. Will be measured at LLNL.
- Density, porosity, thermal conductivity, heat capacity, acoustic properties, and tensile, compressive, and deformation strength, albedo and spectra, will be measured at ARC (Fig. 5) [12-15].

III. ASTEROID SURFACES

- The gas-rich regolith breccias (with characteristic light-dark texture) are samples from the very surface of their parent asteroids and provide unique information on the surface of asteroids (Fig. 6, [16]).

CONCLUSION

- Meteorite studies constitute an integral part of the Nation's planetary defense efforts alongside NEA characterization, numerical studies of reentry, risk analysis, and deflection techniques [17].

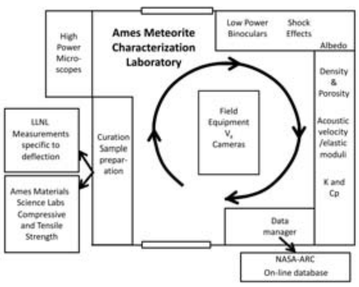

Fig. 6. The ARC laboratory: The systematic measurement of the physical properties of meteorites.

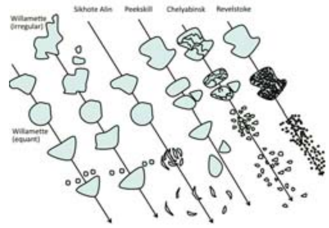

Fig. 1. Observed falls suggest a wide variety of behavior in the atmosphere.

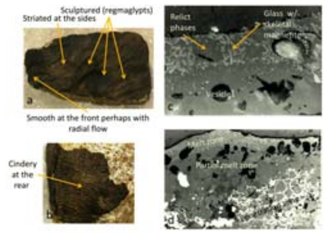

Fig. 2. Fusion crust: Quantitative information on atmospheric passage.

Fig. 3. Craters with meteorites: A test for numerical models.

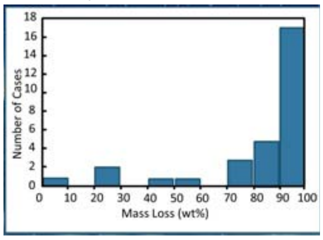

Fig. 4. Cosmogenic studies: Most meteorites undergo >90% mass loss, 25% show relatively little.

Fig. 5. Internal structure of meteorites: Major factor in the atmospheric behavior of meteorites.

Fig. 7. The Fayetteville meteorite: The surface of an asteroid

REFERENCES/NOTES

References/Notes: [1] Popova et al. 2013. Science 342, 1069. [2] Brown et al 2013. Nature 503, 238. [3] Gehrels 1994. "Hazards due to Comets and Asteroids". [4] Belton et al. 2004. "Mitigation of Hazardous Comets and Asteroids". [5] Sears, 1974. PhD Thesis. [6] Carr, 1970. GCA 6, 689. [7] Jenniskens et al. 2012. Science 338, 1587. [8] Popova et al 2010. MAPS 46, 1525. [9] Halliday et al 1981. JRAS Canada 75, 247. [10] Sears and Mills 1973. Nature Physical Science 242, 25. [11] Sears 1978. "Nature and Origin of Meteorites". [12] Koeberl 1998. In "Geol. Soc. Lond. Spec. Pub. 140", 133. [13] Wood 1963. In "Moon, Meteorites, and Comets". [14] Britt and Consolmagno 2003. MAPS 38, 1161. [15] Consolmagno et al. 2013. PSS 87, 146. [16] Goswami et al. 1984. SSR 37, 111. [17] We are grateful to NASA's NEO office for supporting this work.