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Interstellar Matter; Influx and Efflux to and from the Solar System

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Discovery of the first interstellar asteroid, I1/'Oumuamua, entering the Solar System prompts renewed interest in data from other techniques and mass regimes. Searches for interstellar dust in spacecraft data were made in the 1970s (Pioneers 8 ,9 in heliocentric orbits between 0.8 AU and 1.25 AU), but first discovery came from the Ulysses dust experiment (Grun et al. 1994: A&A 286, 915) at $\sim$3 AU; interstellar dust with, masses 10^{-18} to 10^{-13} kg (radii, a $\sim$ 0.05 – 2 μm) was found streaming through the Solar System from motion within the local star field. It was subsequently confirmed in Galileo and Cassini measurements; Cassini's CDA Chemical Analyser measured their composition, showing particulates to be processed, rather than primordial interstellar grains (Altobelli et al. 2016). Interstellar components in radar meteoroid surveys (Taylor et al. 1996: Nature 380, 323) with masses $>$ 10^{-10} kg (a $>$ 20 μm) originate from a diversity of directions, and hence different sources.

The arrival of one interstellar asteroid hardly defines a flux, but can place bounds on global solar system and terrestrial influxes. Implications can be considered: 'Oumuamua is from the solar apex, as are the interstellar dust streams, and hence it shares that same region of the ambient interstellar environment. Although the two sources are of extreme mass difference ($\sim 10^{-16}$ kg and 10^8 kg respectively) it is tempting, in the absence of intermediate data, to construct a power law cumulative distribution to bridge the data. Can it offer useful limits?

An alternative route is to *invert* the problem. Namely, using our well explored Solar System, we could calculate the *efflux*. From one star, our Sun, such efflux could then be folded with the local star population. Assuming a quasi-equilibrium situation, our Sun would then experience this as influx from other Stars. One clear interstellar efflux stream comprises β particles, measured on Pioneers 8 and 9, at masses $< 10^{-14}$ kg, comprising ablated or fragmented meteoroids. We also know that Jupiter's gravity nudges nearby lightly-bound objects such as comets originating in the Kuiper belt and Oort/Opik cloud. The random process "converts" such orbits into either bound orbits or unbound heliocentric trajectories, i.e. an interstellar cometary efflux.

The significance of an interstellar influx is high, especially the potential influx of matter previously processed in a planetary environment. In addition to mechanisms here identified, ejecta from the massive late stage planetary bombardment ($\sim$3.9 Ga bp) could export primitive biological material evolved in the first 0.9 Ga. of the Earth. Mimicked in other planetary system , conversely, generating a potential interstellar influx.

A novel efflux mechanism has also been proposed recently (Berera, A. Astrobiology, 2017) based on the discovery of bio-fragments in the Earth's exosphere. If picked up by Earth grazing β meteoroids – they would have a rapid ride into interstellar space. Might we call these β^+ meteoroids? The presentation explores these scenarios.