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The four most common misconceptions concerning the meteoroid environment

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- Meteor science in the United States declined in the early 1970's and was effectively dead a decade later
- Loss of meteoroid experts
 - NASA meteoroid programs disbanded; few remaining SMEs underfunded
 - No NSF funds
- The Meteoroid Environment Office (MEO) was created in October 2004 to restore NASA meteoroid expertise – direct result of the Shuttle Columbia catastrophe
- The MEO has expended considerable effort in combatting misconceptions created by “lay folk” who were called upon to provide meteoroid information/models in the last few decades (and even now)

The four most common misconceptions about the meteoroid environment



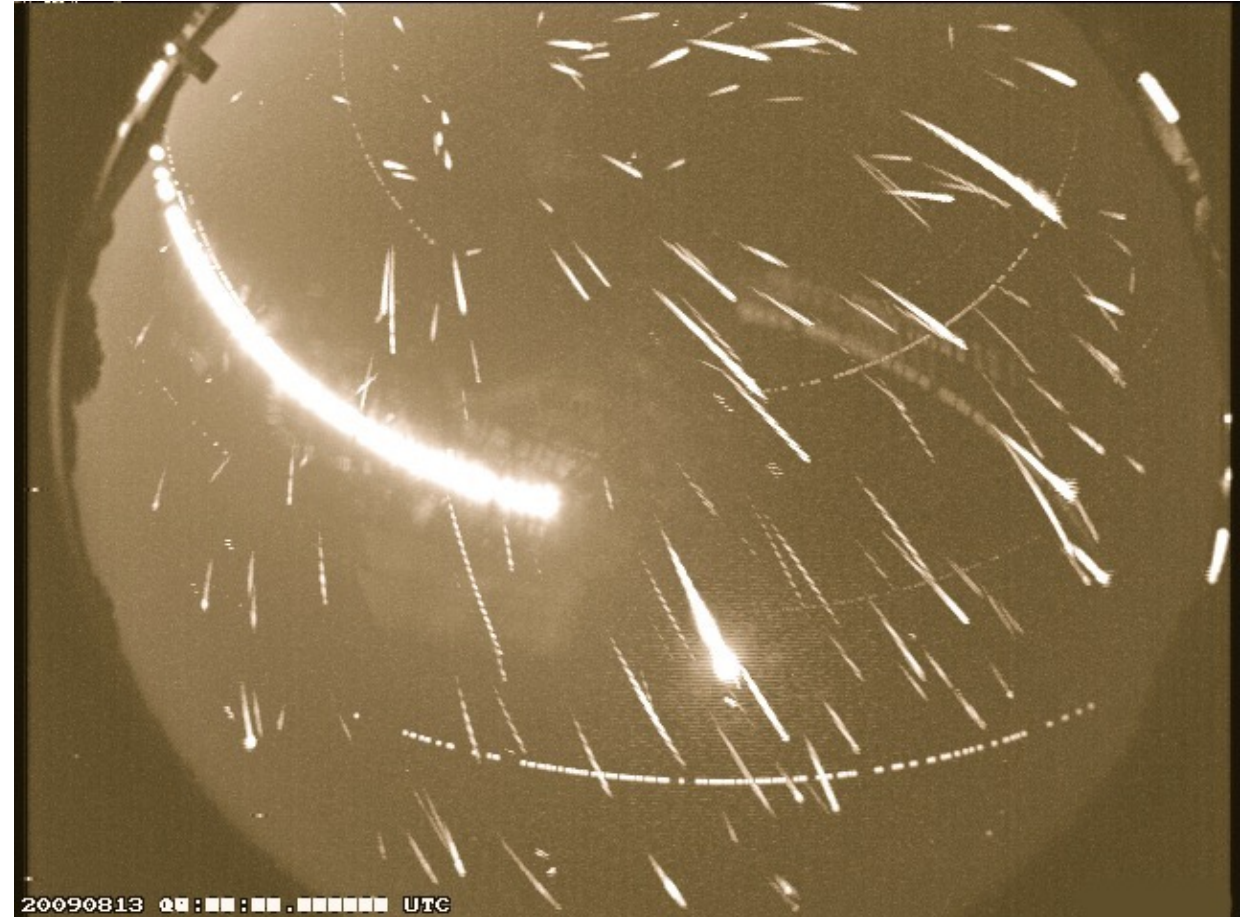
- 1) Meteor showers account for the bulk of meteoroid risk
- 2) Meteoroids are rocks
- 3) The meteoroid environment at the Moon (or Earth-Sun L_1 and L_2) is very different from that in Earth orbit
- 4) Meteor shower activity can always be predicted from past activity

All of these are wrong!

#1 - Meteor showers account for the bulk of meteoroid risk



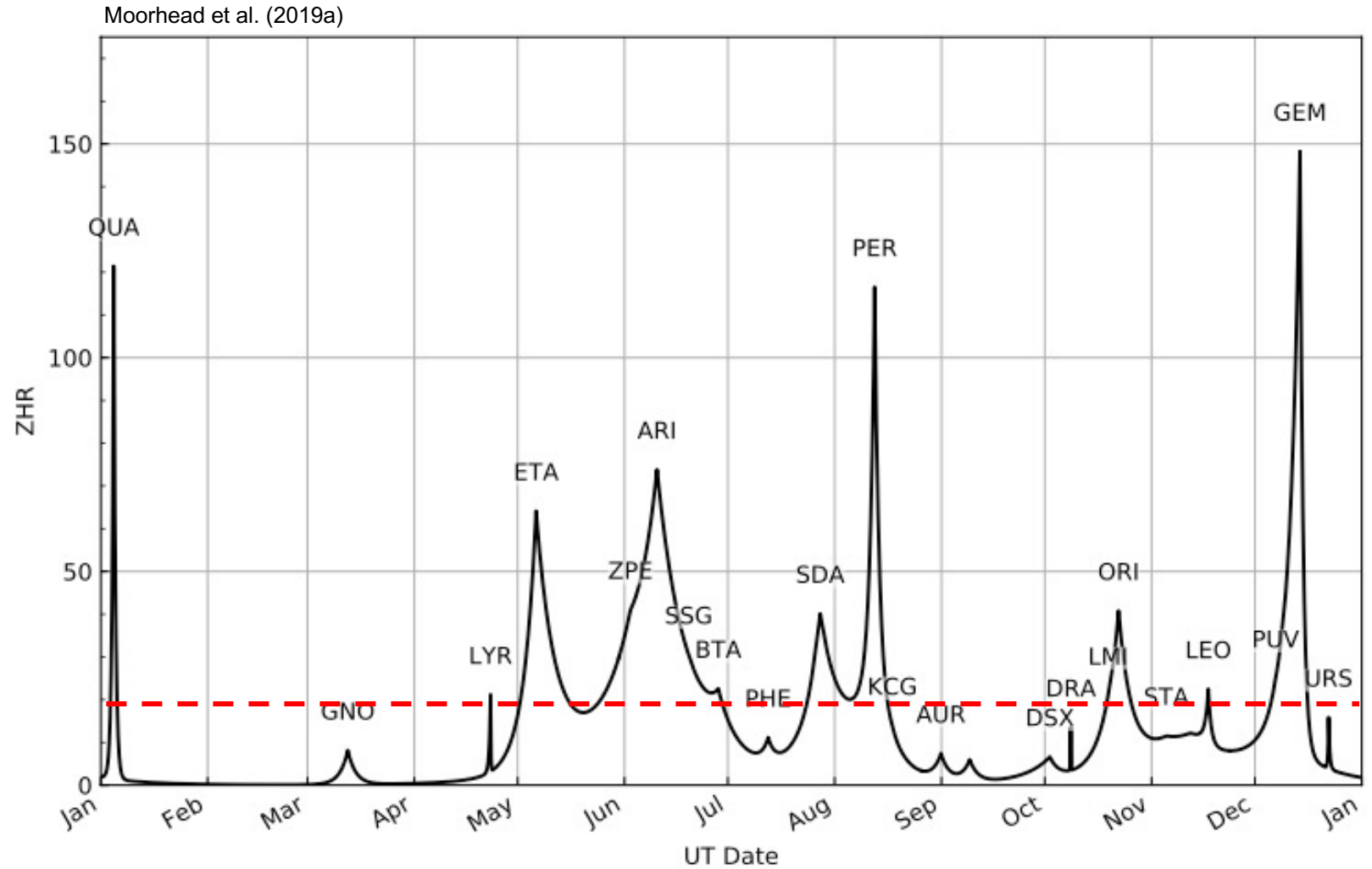
- Meteor showers are visually impressive, with higher rates than the sporadic background ($\sim 80 \text{ hr}^{-1}$ for normal Perseid peak compared to sporadic rates of $\sim 5 \text{ hr}^{-1}$)
- This has led to the common assumption that meteor showers constitute the only times of hazard
- The MEO has fielded many questions about the nature of anomalies occurring during meteor showers



NASA MEO

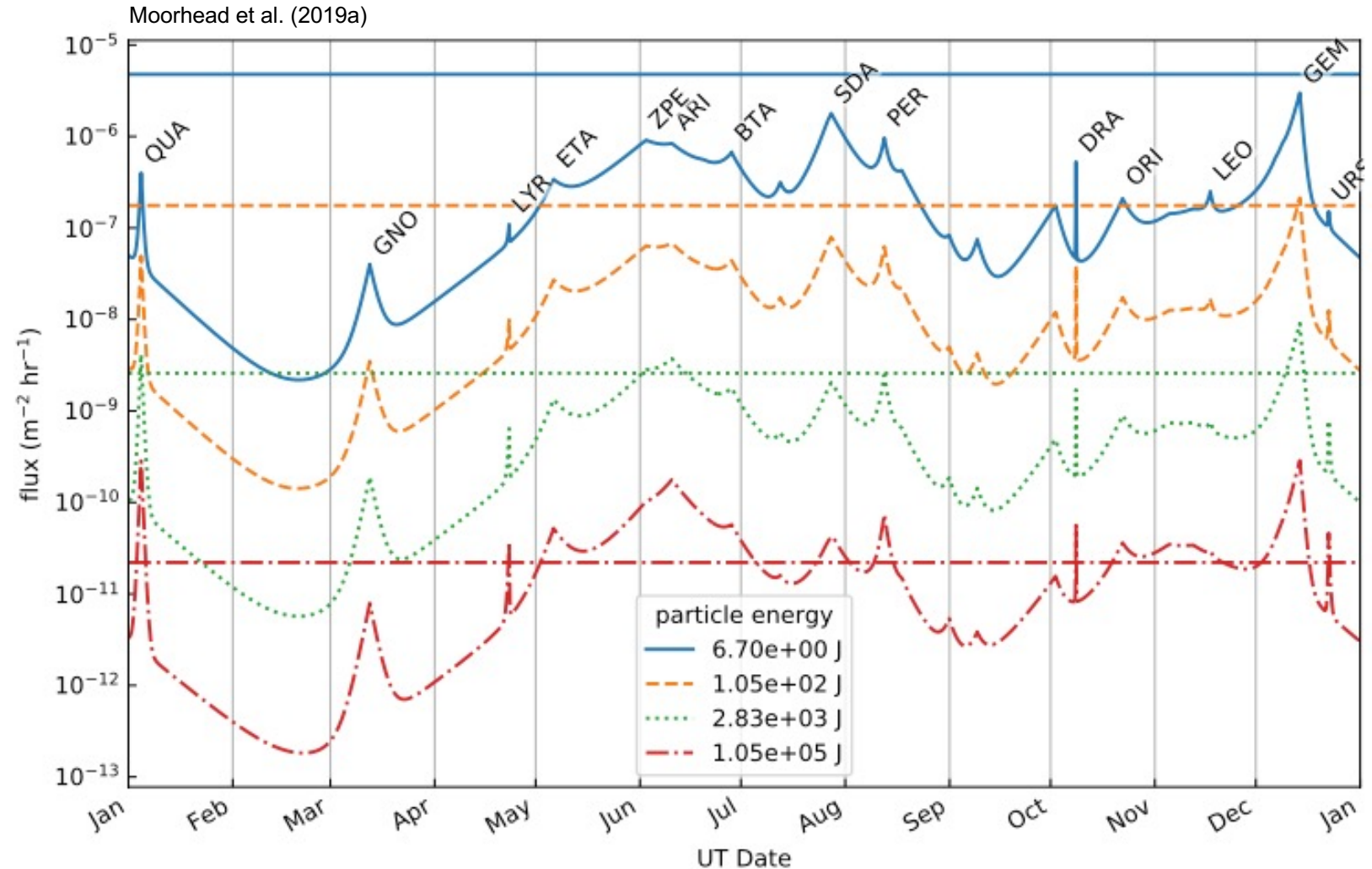
Meteor shower activity during a typical year (includes daytime radar showers)

Dashed red line denotes sporadic background



But when we convert to flux, things look much different...

- At the energy capable of penetrating EVA suits (6.7 J), no shower exceeds the sporadic flux
- Only at higher energies (ISS wall penetrations) do a few showers exceed sporadic levels



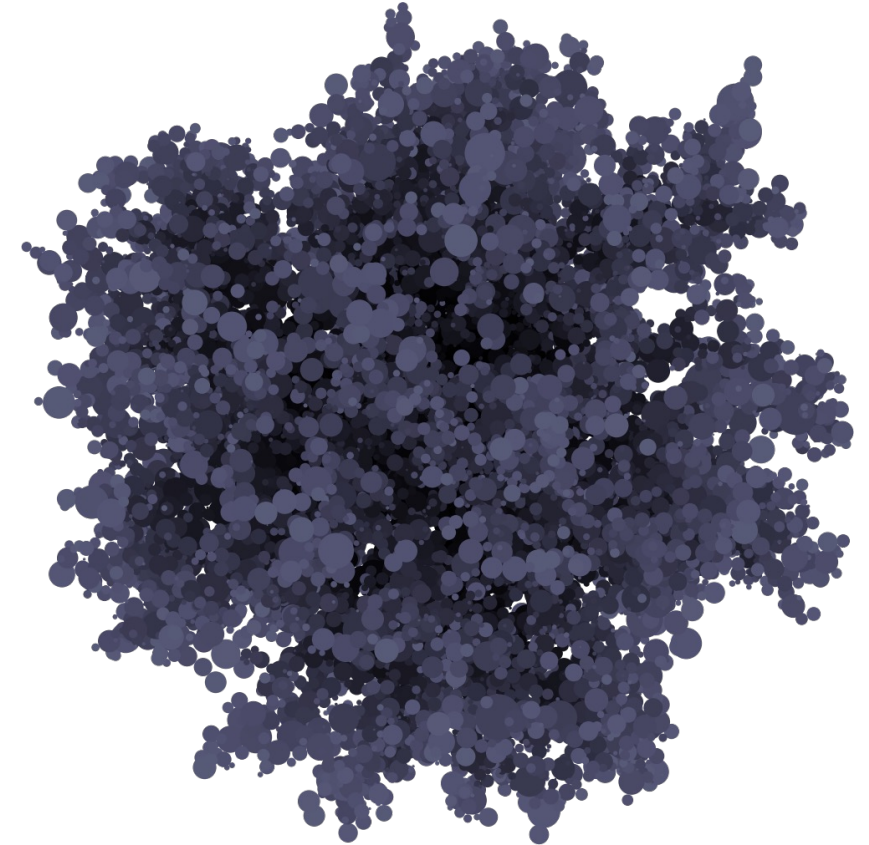
Why?

- The sporadic background is richer in the more numerous mm and smaller particles (bulk of spacecraft risk); showers become important in the cm sizes, where the number and flux of meteoroids is much lower
- Showers with slower meteors have a higher flux than expected from the rates because we only see the high end of the size distribution (slow meteors have to be larger to be detected by optical instruments/radar)
- For more details, see Moorhead et al. (2019b)

#2 – Meteoroids are rocks



- The popular concept of meteoroids is that they are tiny rocks
- Most meteoroids (Nesvorny et al., 2011) are ejected from comets, which are “snowy dirt balls.” Asteroidal material accounts for a small fraction of meteoroids of hazardous size
- Rosetta (Langevin et al, 2016) and high precision meteor observations (Vida et al., 2022) indicate meteoroids are fragile, porous conglomerates with weak structural strengths (as low as kilopascals) and bulk densities less than that of water ice



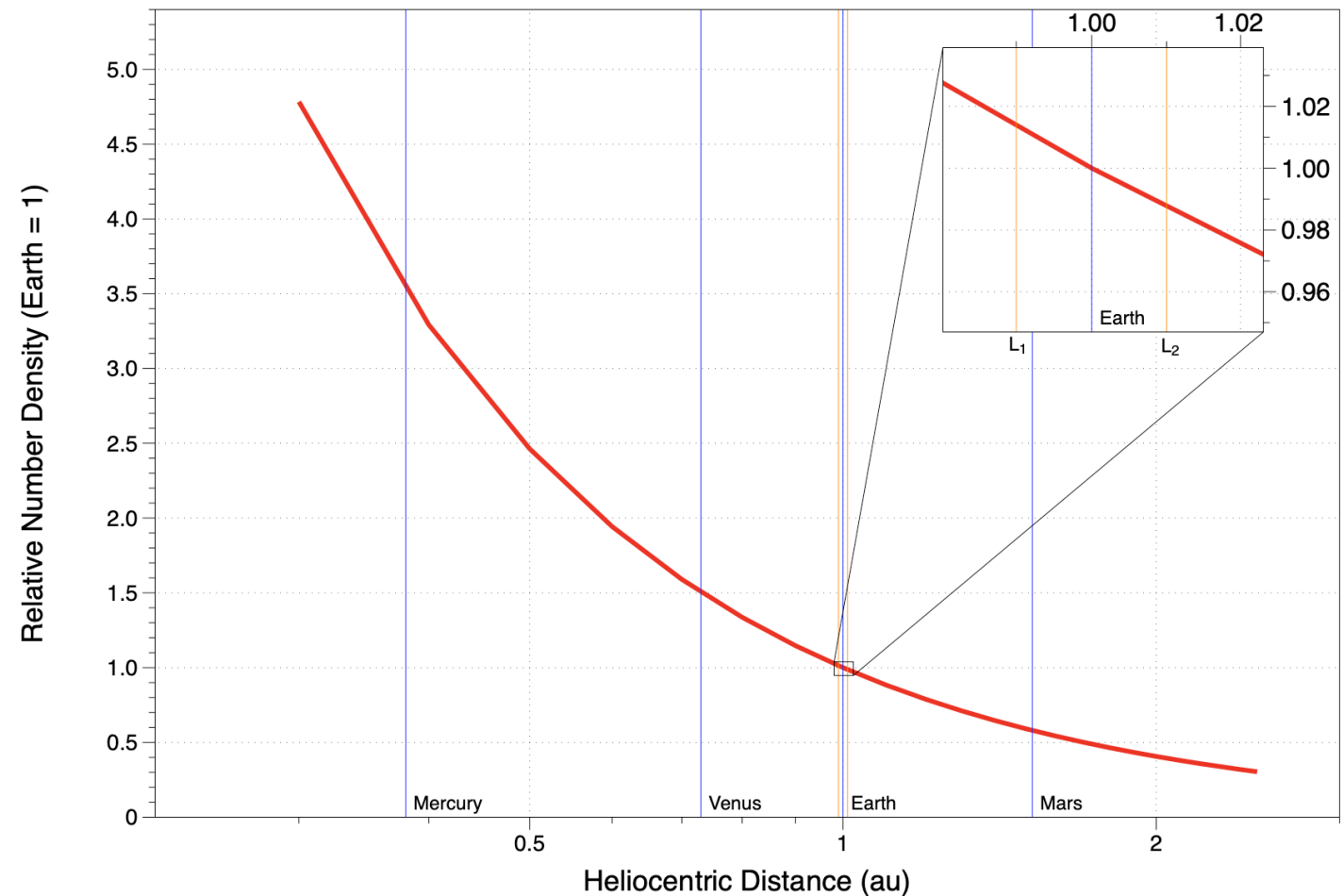
NASA MEO/A. Moorhead

- The structure of meteoroids may explain why, as of this date, there has been no **confirmed** detection of a meteoroid in space by ground based optical and radar
 - Efforts have been made using DoD systems (1960's), Arecibo and Goldstone
 - Practically 0 RCS and low albedo
- All methods of collecting meteoroids do not result in “pristine” samples
 - Volatiles are removed by heating – even affects samples gathered by stratospheric collection or impacts into aerogel
- Applicability of damage equations and hydrocodes developed for OD (aluminum, glass, even meteoritic projectiles) to low strength, high porosity particles?
- Bulk densities and meteoroid structure very active topic of research; low speed meteoroids may have higher proportion of high density objects

#3 – The meteoroid environment at the Moon (or Earth-Sun L_1 and L_2) is very different from that in Earth orbit



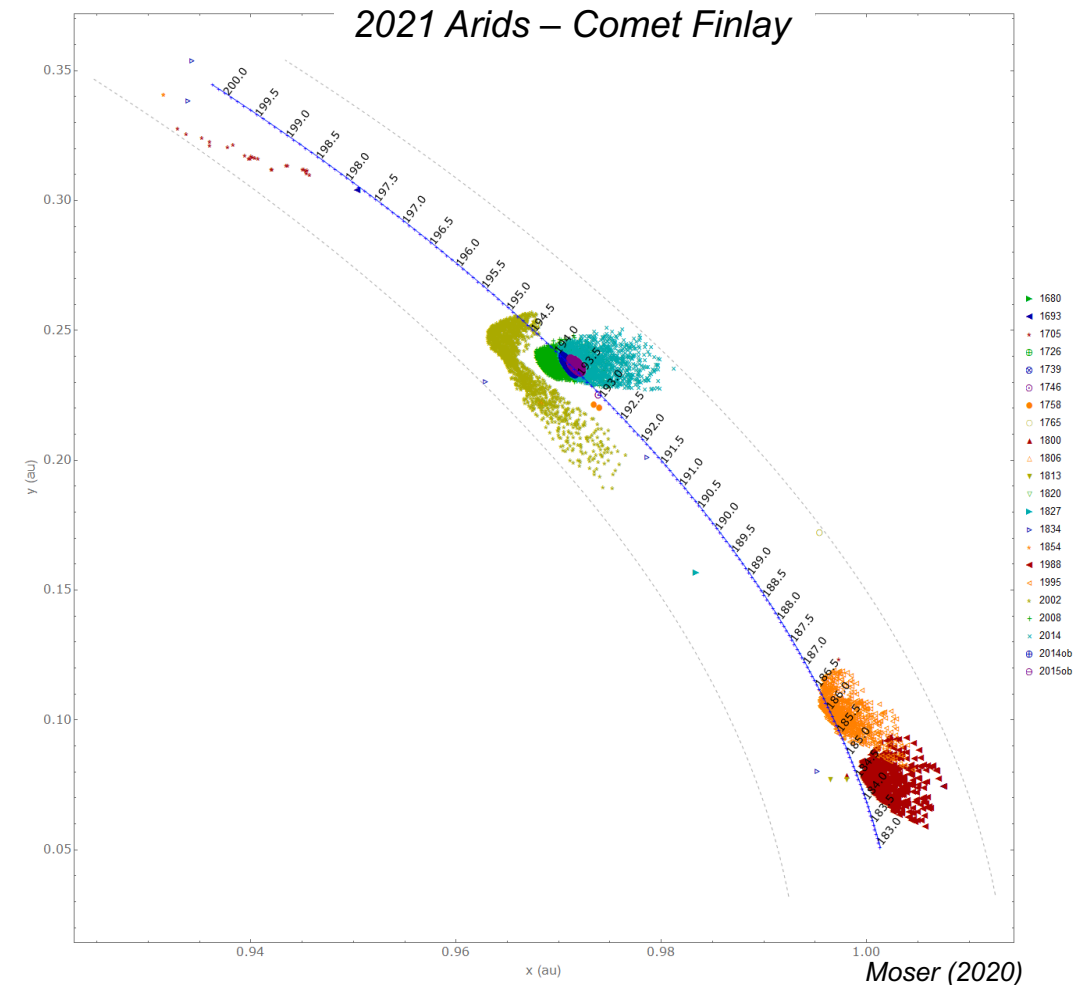
- Zodiacal light (Leinert, 1981) and other observations indicate that the number density of small particles in the inner Solar System falls off slowly with heliocentric distance
- Moon, L_1 , L_2 environments essentially same as Earth (1% difference at L_1 or L_2 , much less at Moon)
- Only difference is grav focusing (energy conservation) and shielding by body (geometry) – local effects on the underlying population



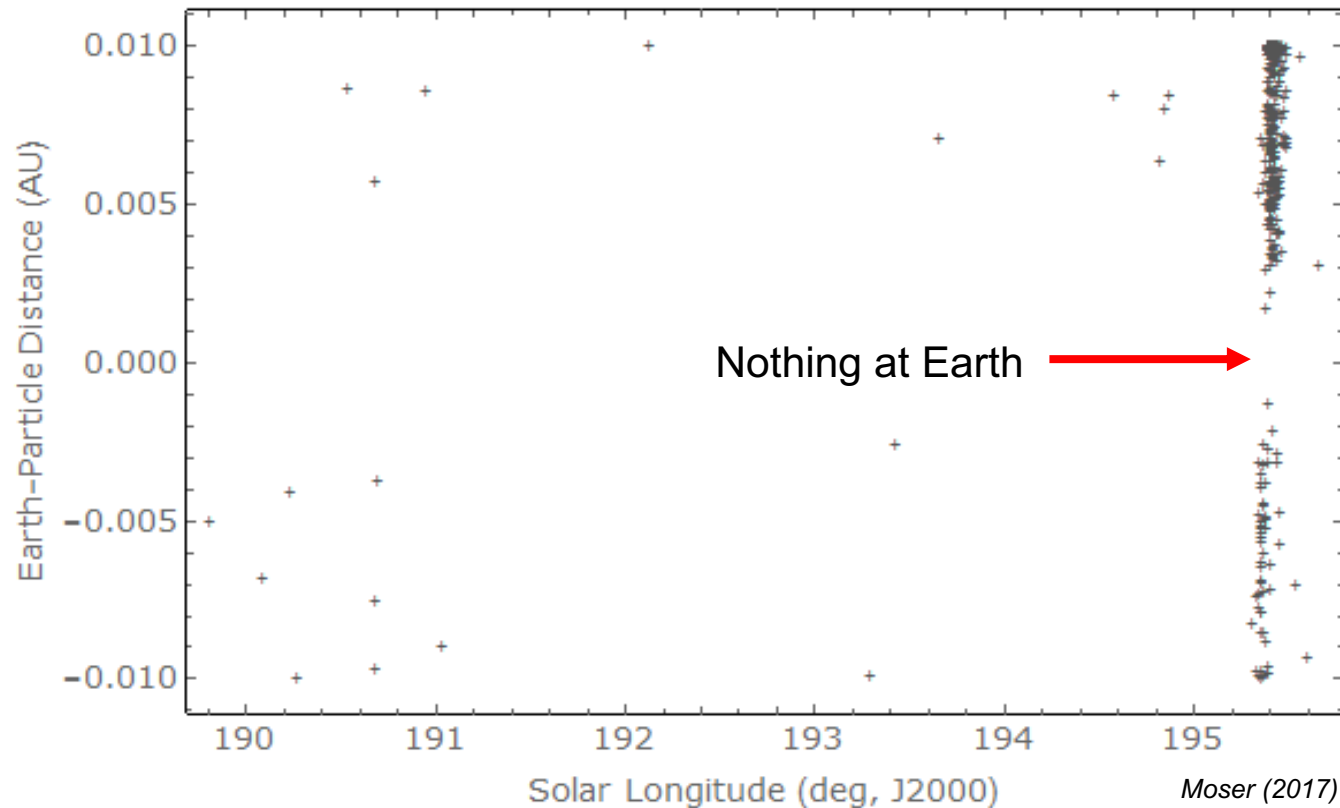
#4 - Meteor shower activity can always be predicted from past activity



- Based on last century notion that meteor shower outbursts or storms only occur in years near comet perihelion
 - The Leonids are the canonical example, but even in this case periodicity is not absolute (no meteor outbursts/storms in 1899/1932)
- The streams of material laid down during each apparition are perturbed by the gravity of the planets (usually Jupiter) with some influence by non-gravs like radiation pressure, etc.
- Streams can be moved towards or away from Earth; past provides calibration points for complex celestial dynamics models



2018 Draconids



- We have known how to do meteor shower forecasting for over a century – just had to wait for computers to get powerful enough to handle complex orbit propagation over hundreds (sometimes thousands) of years for millions of particles
 - This did not occur until the mid-1990's
- Unlike the diffuse sporadic background, dense meteor streams can be narrow enough to affect one location (Earth, L_1 , L_2) without impacting the others

Conclusion



- Many misconceptions exist regarding the meteoroid environment
- Unfortunately some of these make their way into program documents and requirements, inserted there by non-experts
- The MEO has generated a fair amount of information, such as “A Meteoroid Handbook for Aerospace Engineers and Managers” available on NTRS (<https://ntrs.nasa.gov/citations/20200000049>)
 - Also numerous papers in astronomical and engineering journals
- We are working on a meteoroid environment class (SATERN)

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