The primary meteoroid flux at the Moon and at the lunar south pole

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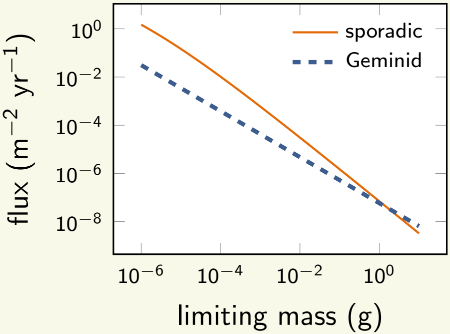
We model shower and sporadic meteoroids separately.

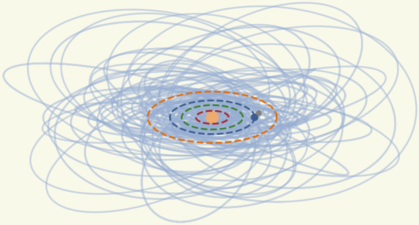
Photographs by David Kingham

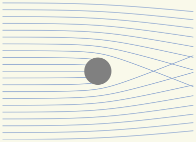
Shower meteors occur at a certain time of year and share similar orbits.

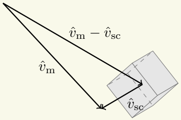
Sporadic meteors occur throughout the year, have varied orbits, and pose more risk [ref].



MEM describes the sporadic component of the meteoroid environment.





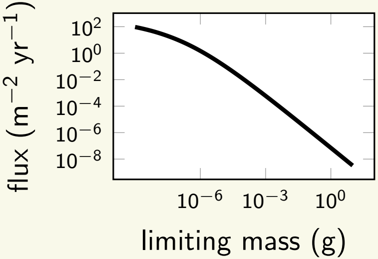


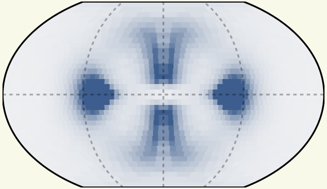
Meteoroid models primarily consist of populations of meteoroid orbits. The environment varies across interplanetary distances, not km, which allows us to extrapolate from Earth-based observations.

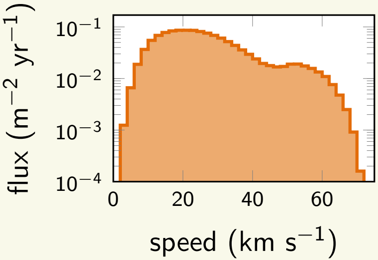
The gravity and size of the Earth and Moon affect the local environment, and the spacecraft's motion factors in to the apparent velocity of the meteoroids it encounters.

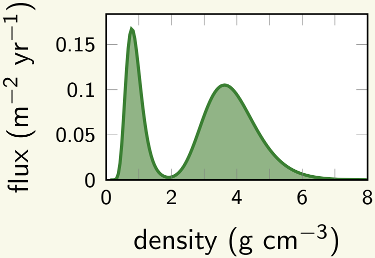
MEM then describes the resulting environment relative to a given spacecraft trajectory [ref, ref, ref, ref, ref].

MEM provides impactor size, angle, speed, and density.

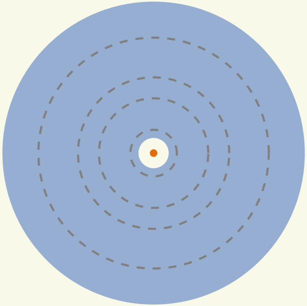


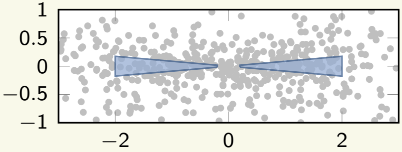






MEM has limitations that we'd like to eventually remove.

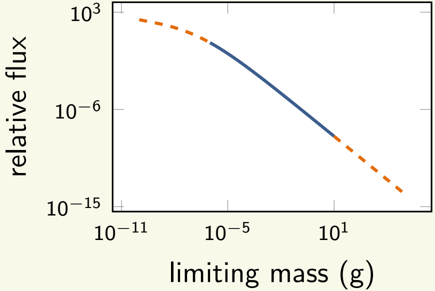




Limited to inner solar system: 0.2 – 2 au

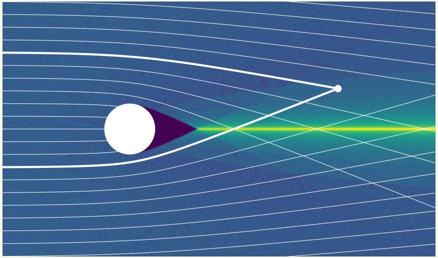
Limited to within $\sim 5^\circ$ of the ecliptic

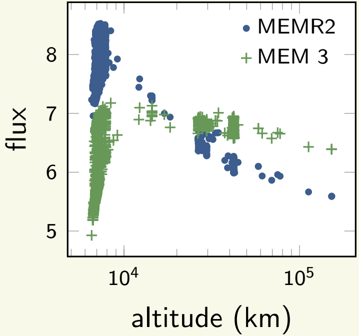
Limited to 10^{-6} – 10 g



MEM 3's improvements include a correct handling of planetary gravity

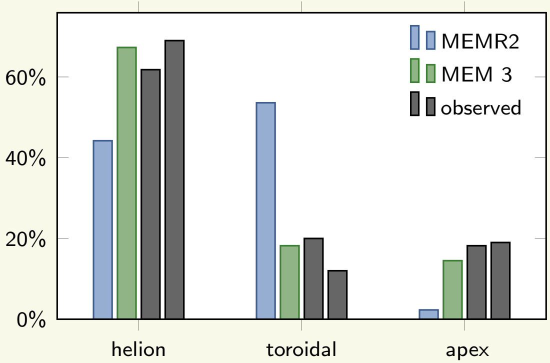
Planets (and moons) bend and block the paths of meteoroids

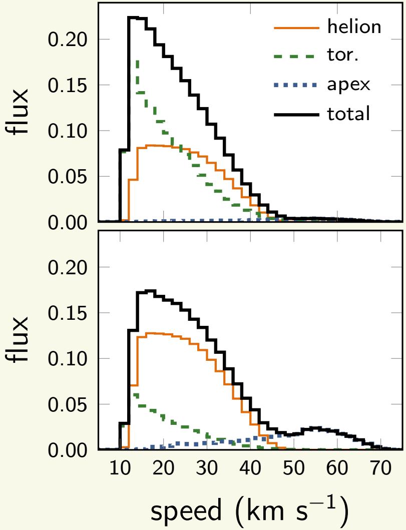




This effect was erroneously large in MEMR2, and has been corrected in MEM 3. The flux is now lower at low altitudes and higher at high altitudes.

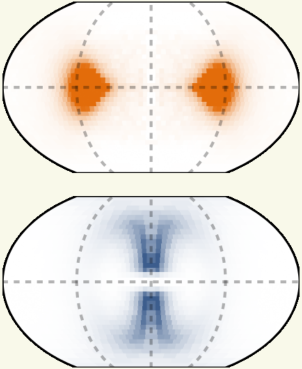
MEM 3's orbital populations match their observed strength at Earth.

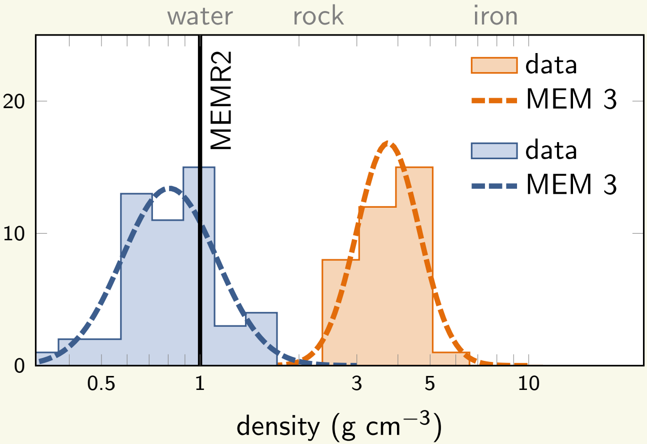




This re-weighting of the orbital populations also changes the speed distribution.

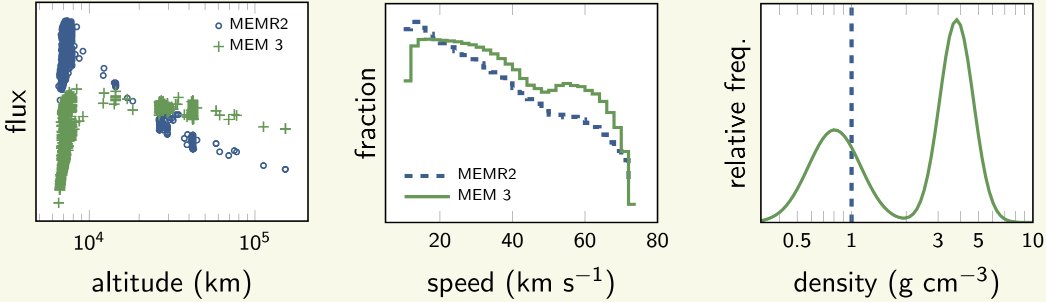
MEM 3 introduces a new, bimodal density distribution.





This distribution is based on detailed modeling of meteors in the atmosphere [ref, ref].

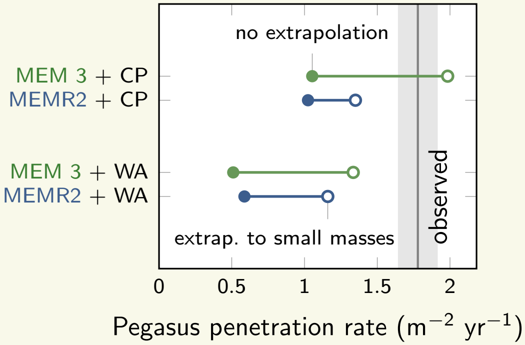
MEM 3 predicts a higher risk for most spacecraft.

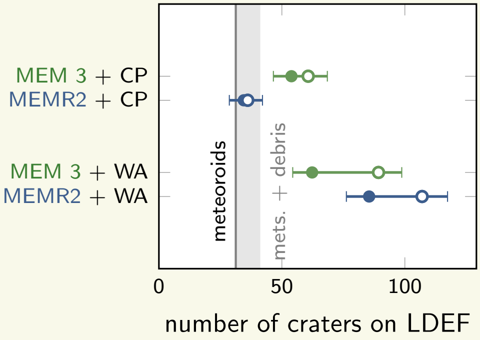


MEM 3 has higher flux (at some altitudes), faster speed distribution, and new high densities. All of these factors will increase the risk [ref].

How do we know that's justified?

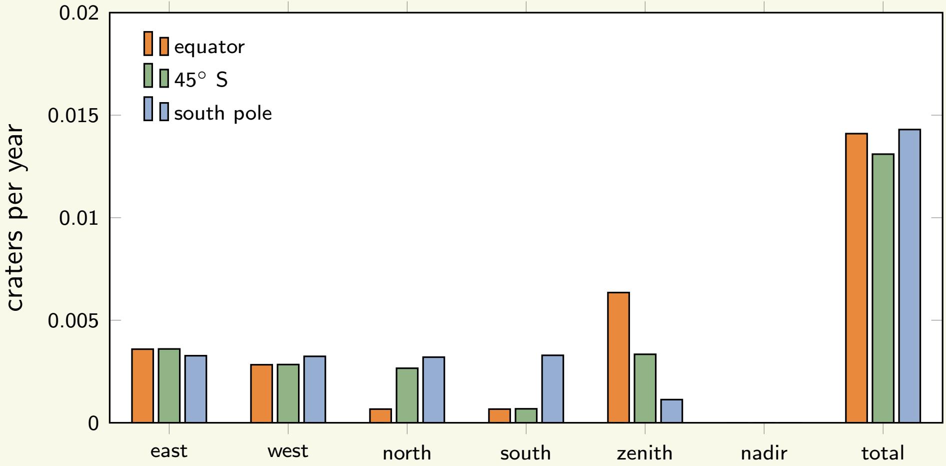
MEM 3 matches the available *in situ* data.





MEM 3 lies between the two best sets of *in situ* data we have in the threat regime: 1 μg - 1 g [ref]

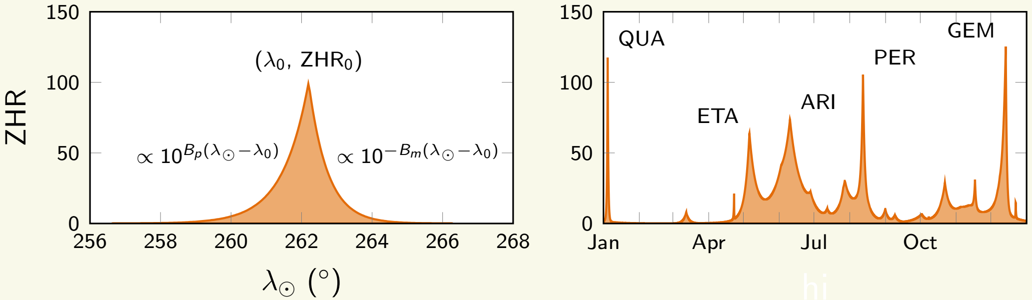
Cratering rate at the Moon (2-mm-deep in aluminum)



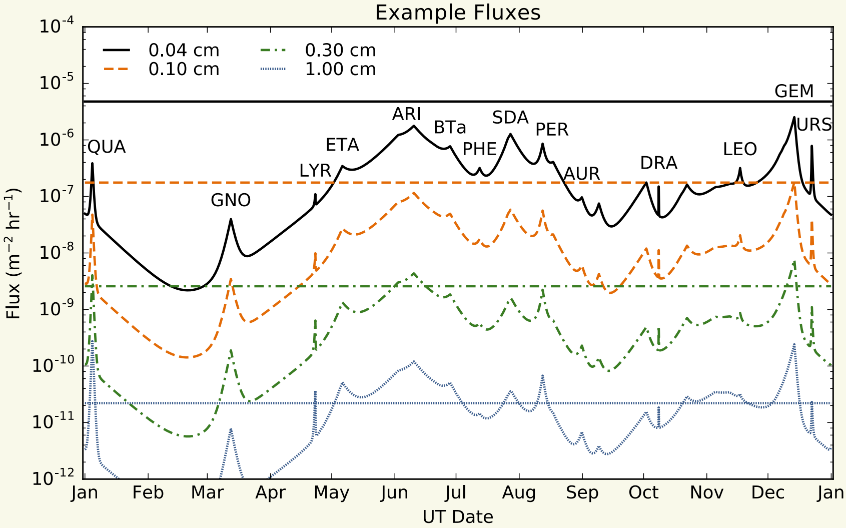
Meteor showers are a small but varying fraction of the environment.

Shower meteoroids constitute 1-5% of the risk, but this risk varies with time.

We handle meteor showers in separate “forecasts” that describe their activity over the course of a year



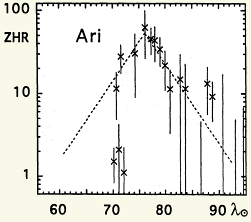
ZHRs are converted to flux for a given altitude and limiting parameter.

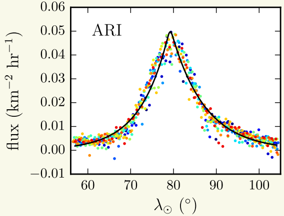


We made a series of improvements starting in 2016.

- 2020 — Radiant dispersions
- 2019 — Gravitational focusing
- 2018 — Other altitudes
- 2016 — Code & data updated
- 2014 — Python version
- 1998 — First forecast

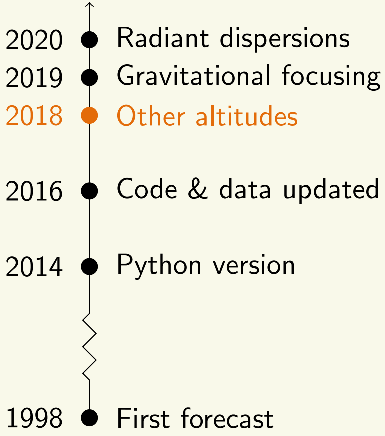
First, we updated many meteor shower activity profiles using data from CMOR ...



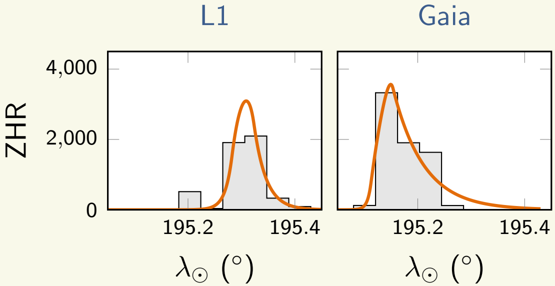


Second, we updated the algorithms. For instance, we improved our calculation of the average shower contribution to the meteoroid flux [ref]

We expanded the code to handle other altitudes in 2018.



We generalized the code in 2018 to handle additional altitudes, the Moon, and Lagrange points [ref]



This was done in part to enable a 2018 Draconid forecast near L1 and L2.

We can now generate forecasts for specific trajectories.

- 2020 Radiant dispersions
- 2019 Gravitational focusing
- 2018 Other altitudes
- 2016 Code & data updated
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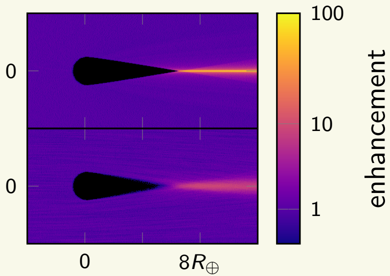
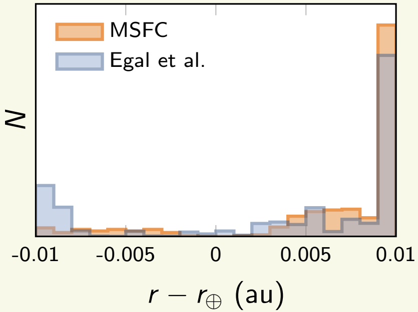
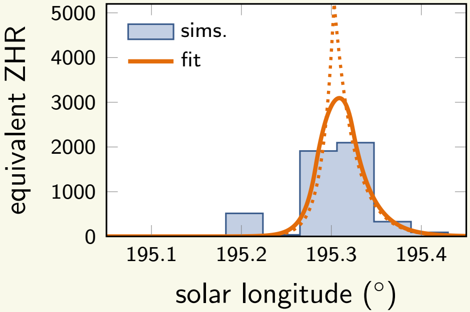
In 2019, we incorporated local gravitational focusing and planetary shielding. In 2020, we improved this to take stream dispersion into account [ref].



Particularly tricky showers may require more extensive modeling.

We and colleagues at the University of Western Ontario conducted detailed simulations of the Draconids in advance of our 2018 and 2019 forecasts [ref].





Based on these simulations, we issued an advisory for the Sun-Earth L1 point.

NASA METEOROID ENVIRONMENT OFFICE

The 2020 meteor shower activity forecast for the lunar surface

Issued 8 November 2019

The purpose of this document is to provide a forecast of major meteor shower activity on the lunar surface. While the predictions in this document are for the surface, spacecraft orbiting the Moon at low altitudes will encounter meteoroids at similar rates. Typical activity levels are expected for nearly all showers in 2020; only the Geminids, which are gradually increasing in strength over time, are expected to be stronger than in previous years. No meteor storms or outbursts are predicted for 2020.

1 Overview

No meteor shower outbursts are predicted for 2020. The fluxes and enhancement factors in this document correspond to the "typical" level of activity of the showers in our list in most cases. We have made

Summary

MEM is our sporadic environment model:

- It covers the bulk of the meteoroid environment and is useful during the design phase of a mission.
- MEM 3 was released mid-2019 and offers many improvements over previous versions. It predicts higher risk but matches meteor and impact data.
- It's the most appropriate tool for simulating the primary meteoroid flux onto the Moon.

Separately, we issue meteor shower forecasts:

- The code we use has gradually increased in complexity and fidelity and is beginning to resemble MEM.
- Inputs are based on both typical shower activity and model predictions.
- We have begun to issue forecasts specific to the lunar surface.