NASA METEOROID ENVIRONMENT OFFICE

The 2021 meteor shower activity forecast for the lunar south pole

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The purpose of this document is to provide a forecast of major meteor shower activity at the lunar south pole. Most major showers are expected to exhibit typical activity, but the "Finlayids" (a possible new shower originating from comet 15P/Finlay) may produce an outburst. The Andromedid and Aurigid showers may also outburst in 2021, but these showers are not visible from the lunar south pole.

1 Overview

This forecast is specific to the lunar south pole and therefore includes only those showers that are visible at that location. The Moon has both a slow rotation period (about 27 days) and a small axial tilt relative to the ecliptic plane (about 1.5°). Thus, shower radiants that are not visible from the lunar south pole at the time of the shower's peak will generally remain unseen for the entire duration of the shower. We find that more than half of the showers in our nominal shower list will not be visible from the lunar south pole in 2021, including many well-known showers such as the Perseids.

Two possibly outbursting showers – the Andromedids and the Aurigids – will also be invisible at the lunar south pole. However, the predicted "Finlayid" shower has a radiant that lies well to the south and will be capable of producing an appreciable flux at the pole. Further discussion of these showers is available in the meteor shower activity forecast for low Earth orbit [1].

This document is designed to supplement risk assessments that use sporadic meteoroid models such as NASA's Meteoroid Engineering Model, MEM [2]. The meteor shower fluxes generated here are therefore weighted to a constant kinetic energy and compared with an estimate of the sporadic meteoroid flux [3]. Meteor shower fluxes drop dramatically with increasing particle energy. Thus, a PNP (probability of no penetration) risk assessment should use the flux and flux enhancement factors corresponding to the smallest particle capable of penetrating a component because the flux at this size will be the dominant contributor to the risk.

An orbiting spacecraft or asset at a different lunar surface location would encounter a different set of showers than those seen from the south pole. Please contact the Meteoroid Environment Office (MEO) with latitude and longitude information if a different location-specific forecast is needed, or with trajectory information if a spacecraft-specific forecast is needed.

2 Details

The expected visual meteor rates (ZHR) for Earth-based observers during calendar year 2021 are available in Figure 1 of Ref. [1]. We have converted these visual rates to particle fluxes, taking into account the biases of the typical human observer, the speeds of the shower meteors, the mass distributions of mete-

kinetic energy	equivalent mass at 20 km s^{-1}	equivalent diameter at 1 g cm^{-3}
6.7 J	3.35×10^{-5} g	0.04 cm
105 J	5.24×10^{-4} g	0.1 cm
2.83 kJ	1.41×10^{-2} g	0.3 cm
105 kJ	5.24×10^{-1} g	1.0 cm

Table 1: The limiting kinetic energies (and their equivalent masses and diameters at 20 km s^{-1} and 1 g cm^{-3}) to which we report fluxes and enhancement factors.

oroids belonging to these showers, and the visibility of shower radiants at the lunar south pole. The result is a flux profile that looks significantly different from the ZHR profile in Ref. [1].

Figure 1 gives the flux profiles for four limiting kinetic energy values, listed in Table 1. The equivalent mass, at a speed of 20 km s^{-1}, and diameter, for a density of 1 g cm^{-3}, are also provided in Table 1. Showers typically contain proportionally more large particles than the sporadic background does; for this reason, showers are more significant at larger particle sizes, masses, or energies. Figure 1 also includes an estimate of the sporadic meteoroid flux for each of these limiting kinetic energies (horizontal lines). Note that for small particle sizes (low kinetic energies), shower fluxes are less significant compared to the sporadic flux. Table 2 lists key characteristics of 5 showers that are visible from the south pole and produce distinct peaks in the flux profile.

In order to facilitate risk assessments, including Bumper PNP calculations, we provide flux enhancement factors for all of 2021 in 1-hour intervals; enhancement factors corresponding to our two smallest limiting energies are presented in Figure 2. These factors represent the increase in the meteoroid flux due to showers over the baseline sporadic flux. The larger flux enhancement factors in Figure 2 correspond to a kinetic energy of 105 J (0.1-cm-equivalent particles), which have lower absolute fluxes.

shower name	radiant		speed	date of maximum
	RA (°)	dec (°)	(km s^{-1})	(UT)
beta Taurids	81	+20	27	2021-06-28 08:51
Southern delta Aquariids	343	-16	41	2021-07-27 22:57
"Finlayids"	259	-48	10	2021-10-07 01:27
Orionids	96	+16	65	2021-10-22 14:47
December Monocerotids	99	+8	41	2021-12-09 07:26

Table 2: Meteor showers producing distinct peaks in the meteoroid flux at the lunar south pole. Radiants are selenocentric and speeds are taken at the lunar surface.

Contact information

The Meteoroid Environment Office will update this forecast as necessary. Those with questions or special needs in the near future are encouraged to contact:

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References

[1] A. V. Moorhead, W. J. Cooke, and D. E. Moser. The 2021 meteor shower activity forecast for low Earth orbit. Issued by the NASA Meteoroid Environment Office on 9 October 2020.

[2] A. V. Moorhead, A. Kingery, and S. Ehlert. NASA's Meteoroid Engineering Model 3 and its ability to replicate spacecraft impact rates. *Journal of Spacecraft and Rockets*, 57:160–176, 2020.

[3] E. Grun, H. A. Zook, H. Fechtig, and R. H. Giese. Collisional balance of the meteoritic complex. *Icarus*, 62:244–272, 1985.

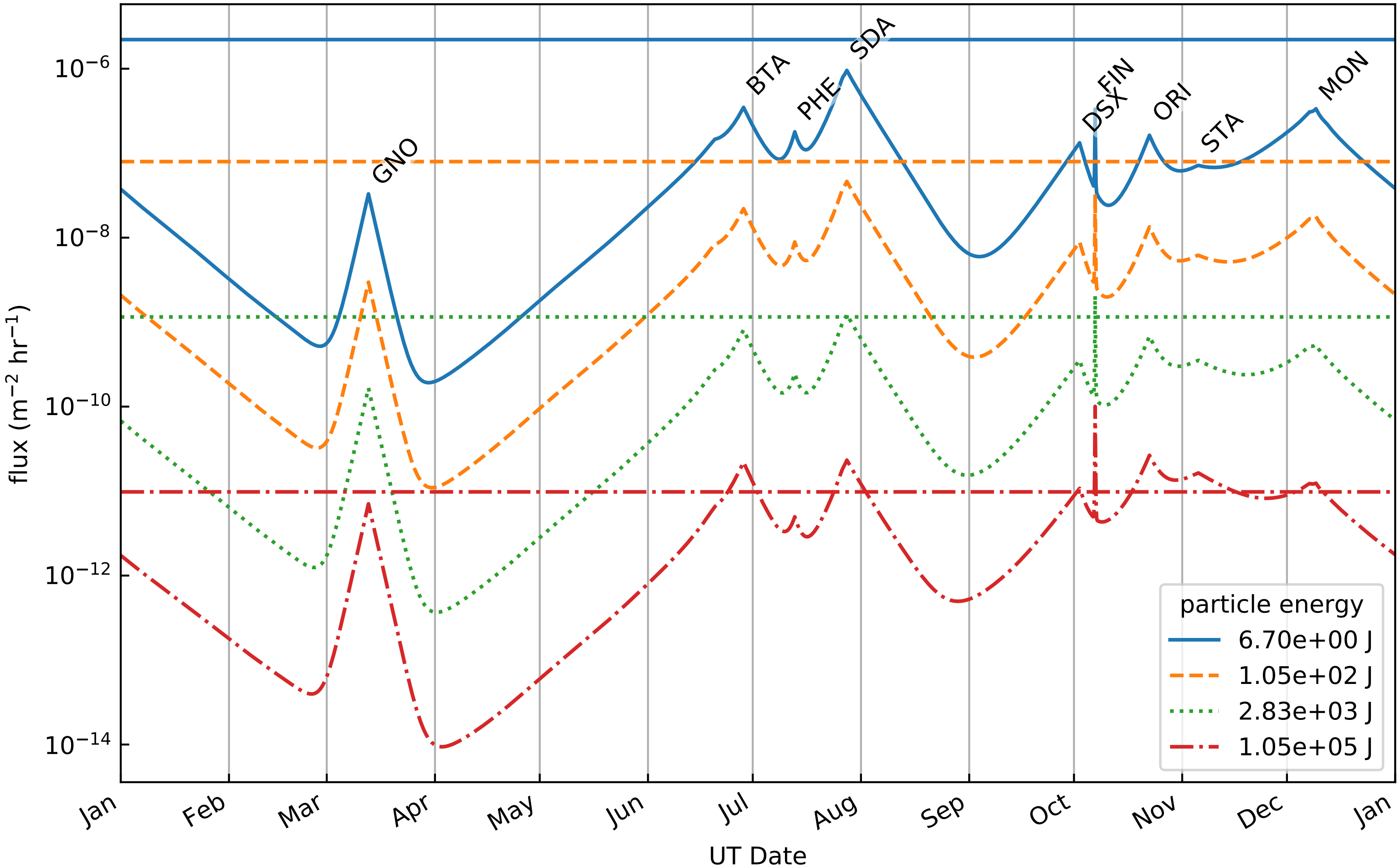

Figure 1: Meteor shower flux (variable lines) and sporadic meteoroid flux (horizontal lines) over the course of 2021. Fluxes are quoted to four limiting particle kinetic energies; these kinetic energies correspond to particles with diameters of 0.04 cm, 0.1 cm, 0.3 cm, and 1 cm, assuming a density of 1 g cm^{-3} and a speed of 20 km s^{-1}.

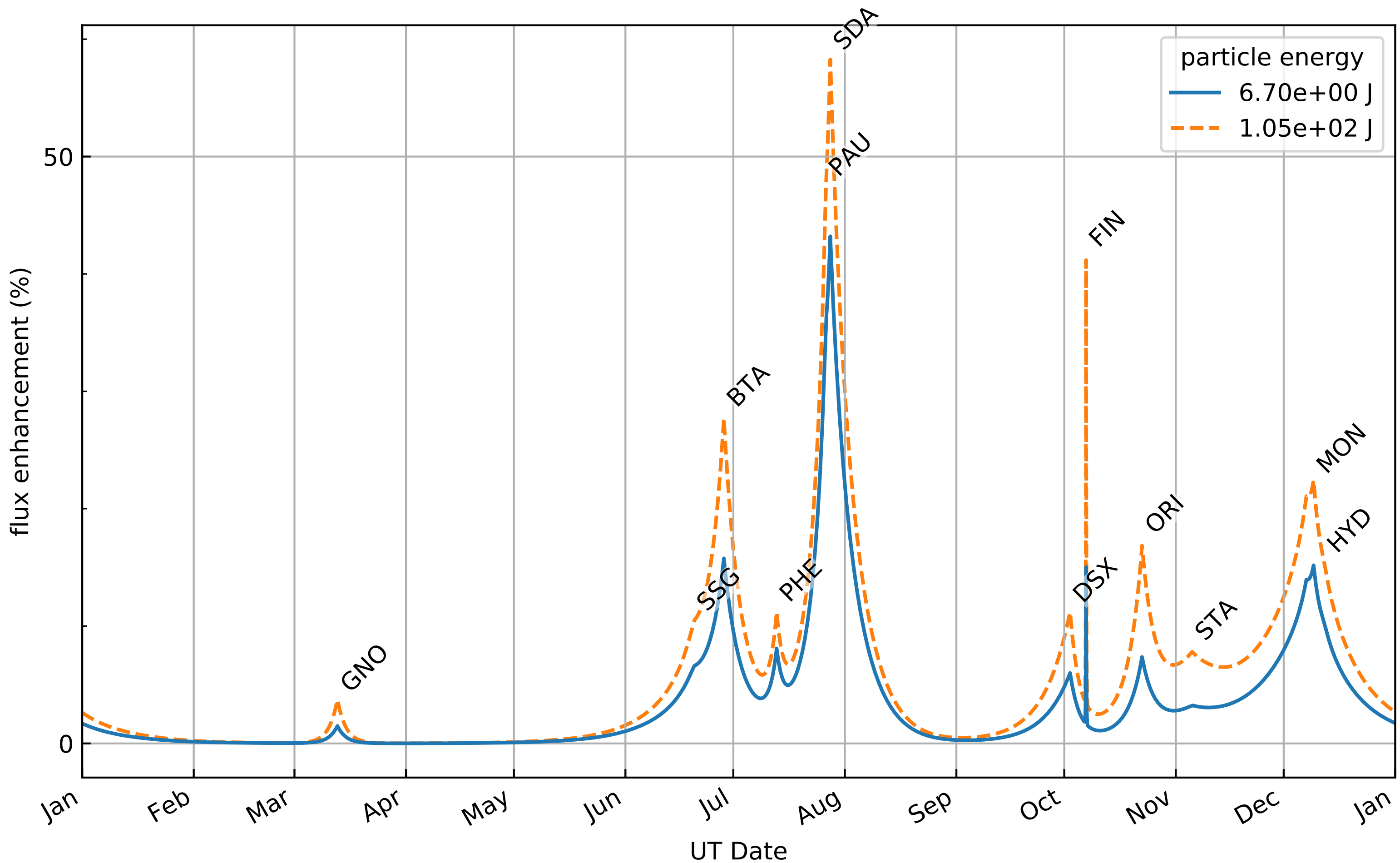

Figure 2: Meteor shower flux enhancement relative to the sporadic meteoroid flux over the course of 2021. These factors can be used in conjunction with a meteoroid model such as MEM to compute the flux at a particular point in the year on a plate facing the shower radiant.