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# Meteor shower forecast improvements from an all-sky survey

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## Meteor Shower Forecasting

Spacecraft and space suits can be damaged by debris impacts: Shuttle and Space Station surfaces are dotted with impact craters, and astronauts' gloves have been damaged by crater-pitted hand-rails. The twin hazards of orbital debris and meteoroids must therefore be taken into account in mission planning.

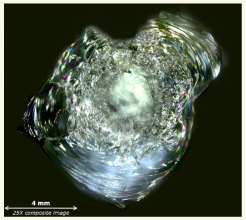

Figure 1: Meteoroid impact on window 6 of Endeavor, incurred during Space Shuttle mission STS-126.[1] The crater was produced by a magnesium-rich meteoroid and has a depth of 0.68 mm.

Image provided by the NASA/JSC Hypervelocity Impact Technology (HVIT) Team.

The Meteoroid Environment Office (MEO) produces annual meteor shower forecasts designed to help spacecraft programs mitigate risk. While the impact risk posed by the steady-state meteoroid background is mitigated via spacecraft design and shielding, the periods of elevated risk posed by meteor showers are more frequently mitigated (if necessary) by adjusting the launch window, EVA period, or spacecraft attitude. An accurate temporal profile is thus critical for successful shower forecasting.

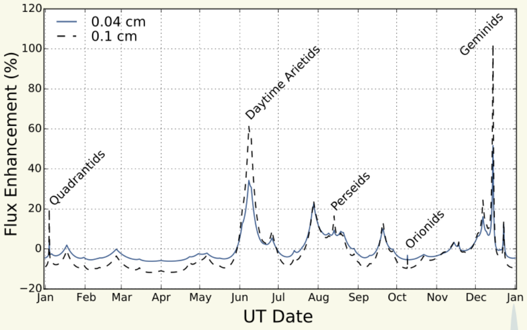

Figure 2: Predicted meteoroid flux enhancement (or diminishment) due to showers over the course of 2015. Because the enhancement is computed relative to the overall meteoroid flux, the integral over the entire year is zero. Note that showers play a larger role at large particle sizes.

## All-Sky Networks

NASA and the University of Western Ontario (UWO) operate sister all-sky networks known as the NASA All-Sky Fireball Network[2] and the Southern Ontario Meteor Network (SOMN).[3] Cameras are grouped in clusters with overlapping fields of view and the ASGARD[3] software detects meteors and calculates trajectories. These networks detect cm-sized meteoroids or larger.

Figure 3: All-sky camera (left) and network map (right).

These networks have measured over 27,000 meteor trajectories. Quality cuts in camera-meteor-camera angle and velocity uncertainty reduce the total to just over 20,000.

## Meteor Shower Detection with DBSCAN

We extract showers from our meteor data using a density-based clustering algorithm called DBSCAN.[4] Our parameter space consists of Sun-centered ecliptic radiant, solar longitude, and geocentric velocity. In order to minimize the number of spurious clusters, we generate clones of our meteor data set using measured uncertainties and apply DBSCAN to each cloned data set. We keep only those showers that consistently appear with at least 5 members. 31 showers satisfy this criterion (see Figure 5), all of which closely match established showers in the IAU Meteor Data Center.

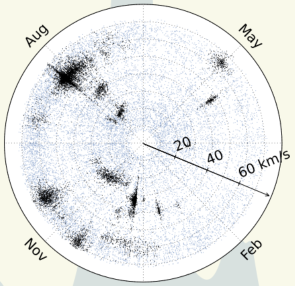

Figure 4: Geocentric velocity (radius) as a function of time of year (angle) for our all-sky data. Shower members are black and sporadic meteors are blue.

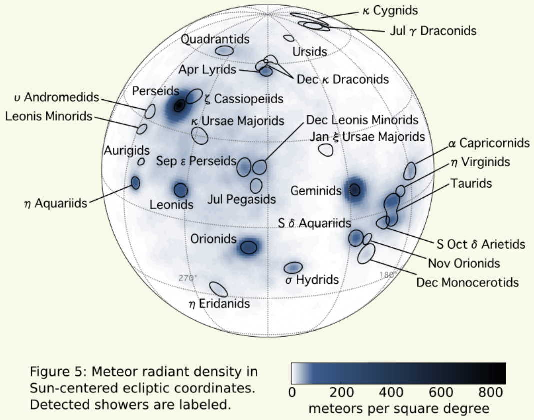

Figure 5: Meteor radiant density in Sun-centered ecliptic coordinates. Detected showers are labeled.

## Shower Activity Profile

Activity profiles are often modeled as double exponential peaks. However, we fit each of the 80 probability distributions in the SciPy[5] package to our data and found that a Johnson $S_U$ distribution performed better overall. These fits can now be used to improve the temporal profile in our meteor shower forecasts.

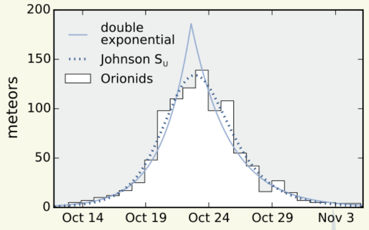

Figure 6: Orionid activity profile

[1] Hyde, J. et al. 2009. JSC-64921.
[2] Cooke, W.J. & Moser, D.E. 2012. PIMO 2012, p9.
[3] Weryk, R.J. et al. 2008. EM&P, 102, p241.
[4] Ester, M. et al. 1996. KDD-96, p226.
[5] Jones, E. et al. 2001. SciPy, online.

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