The use of *D*-criteria to assess meteor shower significance

Introduction

- The anisotropy of the sporadic meteor background complicates meteor shower extraction.
- Using static orbital similarity criteria to identify shower members can produce too many false positives near sporadic sources.
- **Concept:** We use shower "analogs" to characterize the density of meteor orbits in a region of parameter space when the shower is *not* active.

Orbital Similarity Criteria

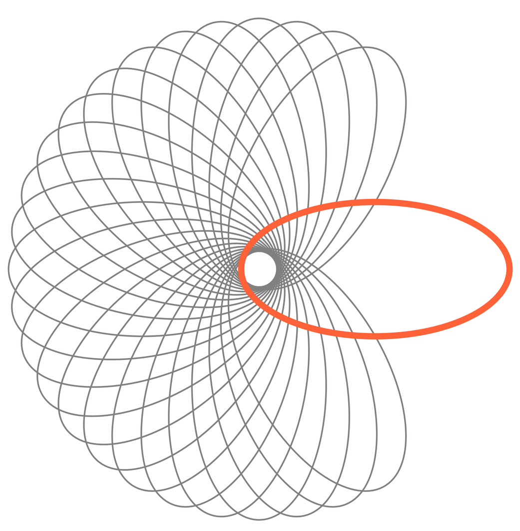
- *D*-parameters quantify orbital similarity.
- We obtained the best results using D_N [1]:

$$\begin{aligned}
\Delta\phi_a &= 2\sin\tfrac{1}{2}(\phi_2 - \phi_1) \\
\Delta\phi_b &= 2\sin\tfrac{1}{2}(\pi + \phi_2 - \phi_1) \\
\Delta\lambda_a &= 2\sin\tfrac{1}{2}(\lambda_{\odot,2} - \lambda_{\odot,1}) \\
\Delta\lambda_b &= 2\sin\tfrac{1}{2}(\pi + \lambda_{\odot,2} - \lambda_{\odot,1}) \\
\Delta\xi^2 &= \min(\Delta\phi_a^2 + \Delta\lambda_a^2,\ \Delta\phi_b^2 + \Delta\lambda_b^2) \\
D_N^2 &= (u_2 - u_1)^2 + w_1(\cos\theta_2 - \cos\theta_1)^2 + \Delta\xi^2
\end{aligned}$$

where $u = v_g/v_\oplus$, $\theta = \cos^{-1}(u_y/u)$, and $\phi = \tan^{-1}(u_x/u_z)$.

- D_N is based on geocentric speed and radiant ($\vec{v}_g$) and solar longitude ($\lambda_\odot$) instead of orbital elements.

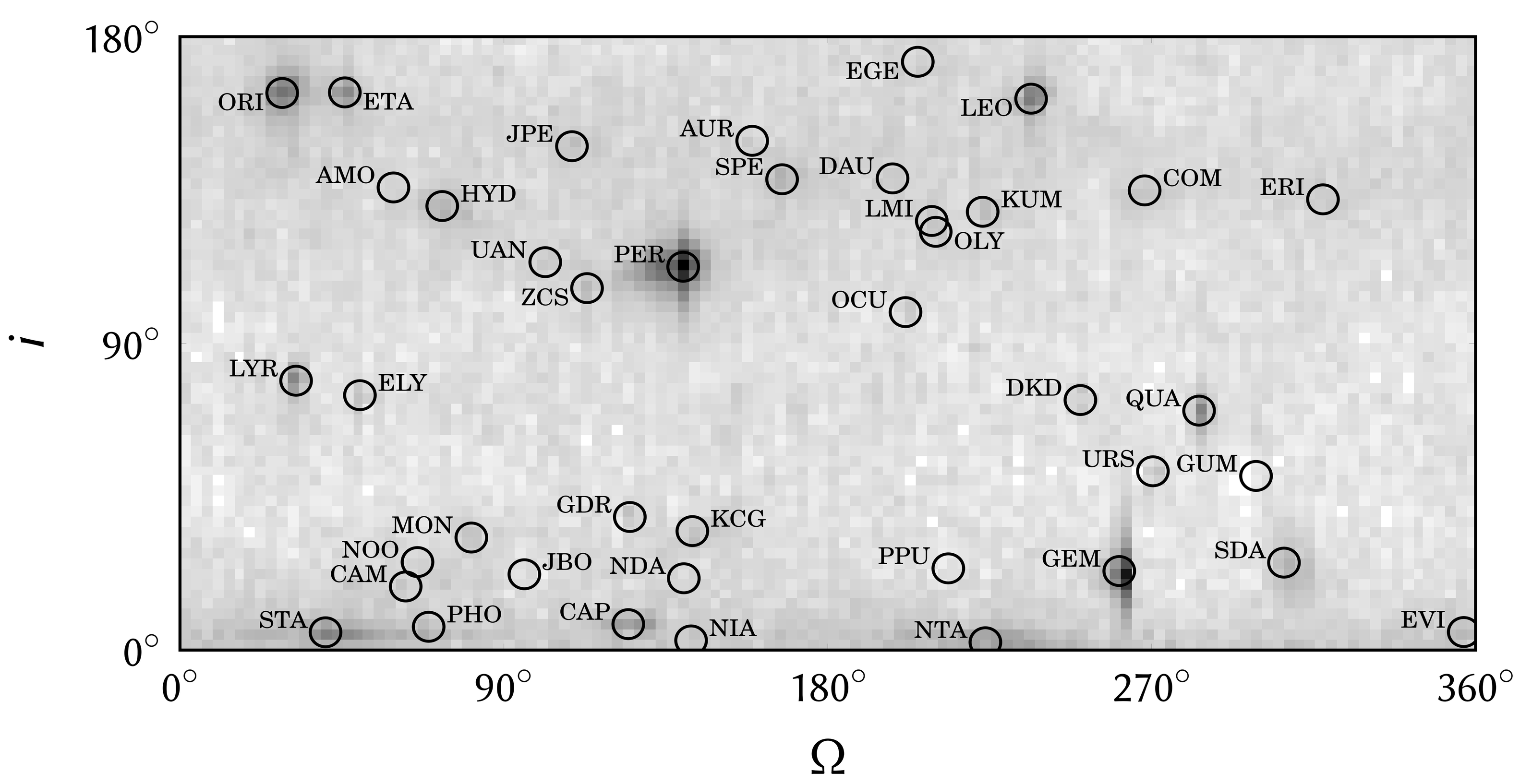
Construction of shower analogs



- We construct a set of analogs for each shower.
- Analogs have the same geocentric speed and sun-centered ecliptic radiant, but are offset from the shower by at least 60° in $\lambda_\odot$.
- This effectively defines a shower as an enhancement lasting $<$ 4 months.
- We calculate D_N of *all* meteors relative to each analog and to the shower and compare.
- This provides us with an estimate of the **false positive rate for shower association** as a function of D_N.

Data

- We apply our method to 36,617 all-sky meteors from NASA All Sky Fireball Network [2] and the Southern Ontario Meteor Network (SOMN) [3].
- Possible showers were identified using orbital element heat maps (see below) or as short-lived clusters of meteors [4]

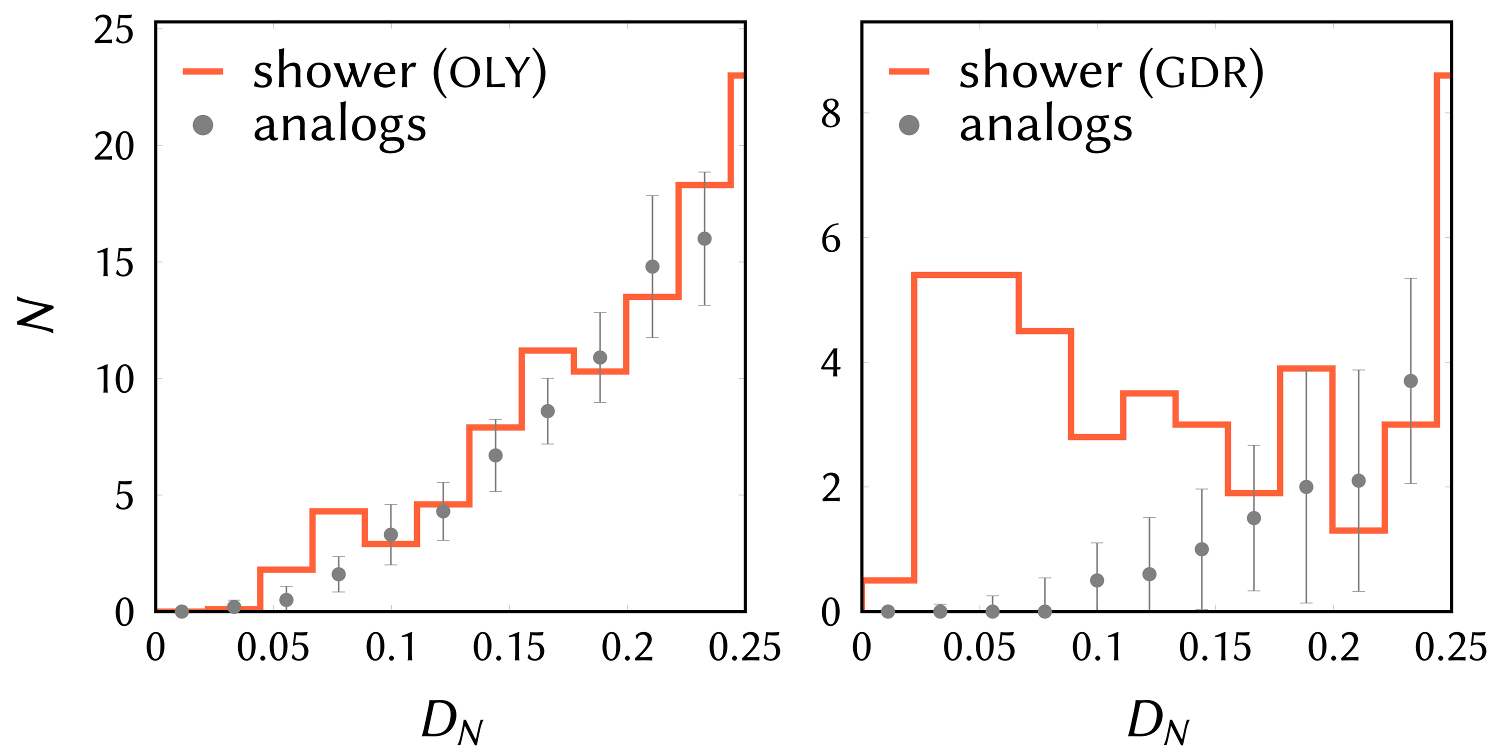


References

[1] Valsecchi G. B., Jopek T. J., Froeschle C., 1999, *MNRAS*, 304, 743-750.
[2] Cooke W. J., Moser D. E., 2011, in Proc. of the IMC, 9-12.
[3] Weryk R. J. et al., 2008, *EM&P*, 102, 241-246.
[4] Burt J. B., Moorhead A. V., Cooke W. J., 2014, *WGN*, 42, 14-19.

Application #1: Testing Shower Significance

- **Example 1:** The October Lyncids (OLY) were not detected: meteor density around the shower and its analogs is similar.
- **Example 2:** The July γ Draconids (GDR) were detected: meteor density around the shower exceeded the false positive rate.



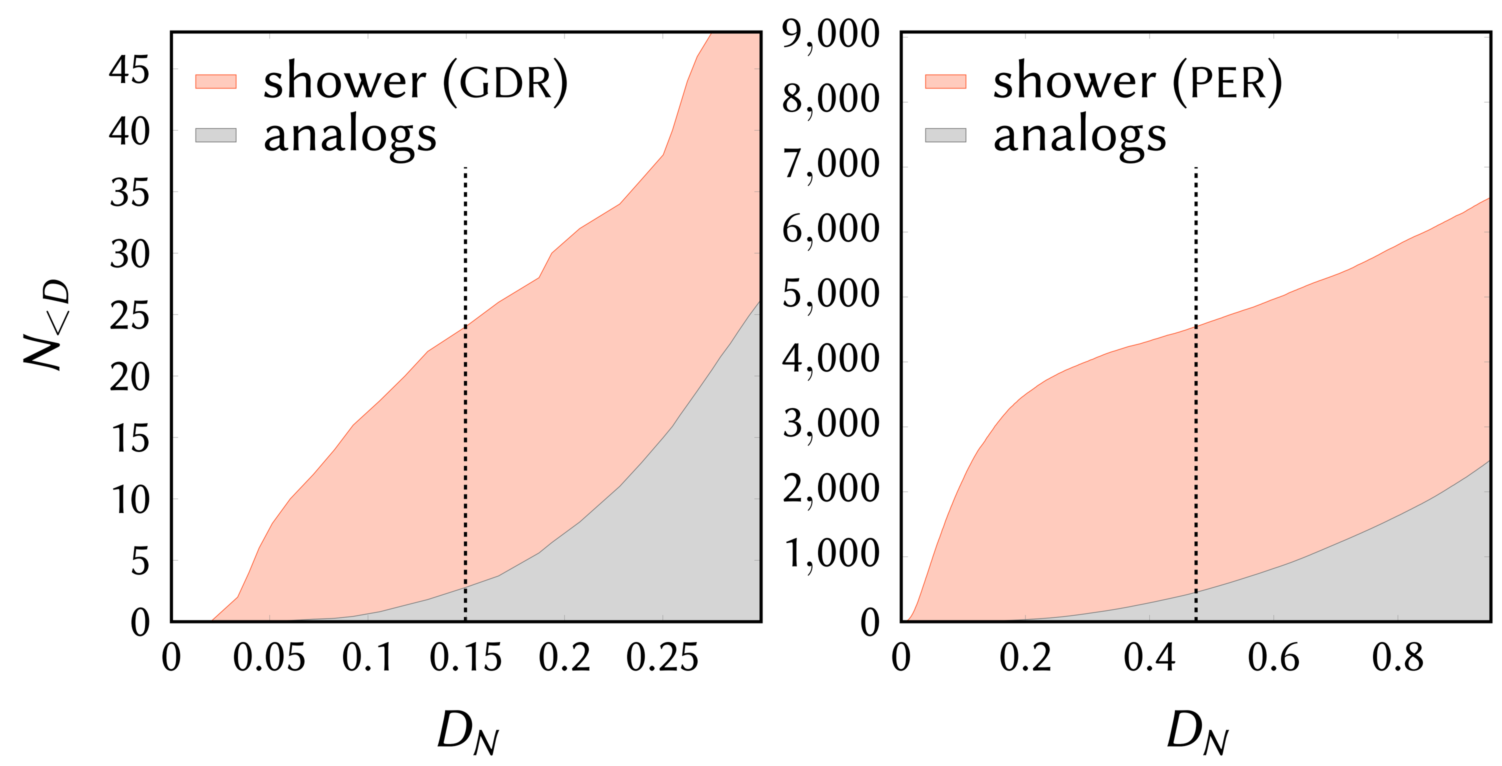
Application #2: Shower membership probability

- The ratio of meteors that lie close to the shower orbit vs. its shower analogs provides an estimate of shower membership probability as a function of *D*:

$$P(shower|D) \simeq \frac{N_D - N_{spor,D}}{N_D}$$

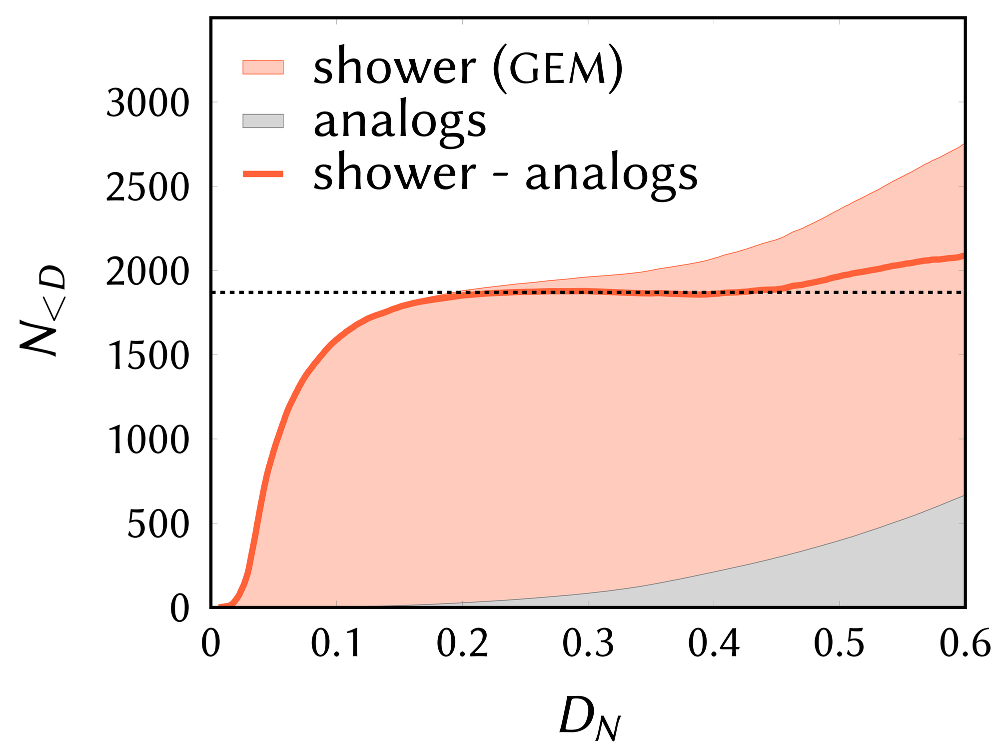
Application #3: Limiting Sporadic Contamination

- Shower analogs yield a false positive rate
- D_{max} can be chosen to limit this to a desired percentage
- **Example 1:** D_{max} = 0.15 limits sporadic contamination to less than 10% for the July γ Draconids (GDR).
- **Example 2:** D_{max} = 0.475 limits sporadic contamination to less than 10% for the Perseids (PER).



Application #4: Shower strength estimates

- It is not necessary to identify each shower member in order to estimate the strength of a meteor shower.
- **Example:** This CDF indicates that we have $\approx$ 1870 Geminids (GEM) in our data set.



Althea V. Moorhead
althea.moorhead@nasa.gov
NASA Meteoroid Environment Office, Marshall Space Flight Center, USA

Read the paper at https://doi.org/10.1093/mnras/stv2610