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Poster
Suprathermal electron pitch-angle distributions (PADs) are instantaneous tracers of magnetic connectivity and heliospheric structure. However, traditional classification often relies on manual inspection or fixed heuristics that struggle to scale with large datasets. We present a fully data-driven, instrument-agnostic framework that employs an unsupervised K-Means architecture to discover a morphological "dictionary" of 32 PAD clusters from 20 years of ACE and STEREO observations.

Despite being physics-agnostic, the pipeline successfully recovers all canonical PAD shapes—including strahl, counterstreaming, and loss-cone types—while uniquely isolating rare morphologies such as pancake and butterfly distributions. Notably, our results reveal a striking co-occurrence of these rare PADs within the most extreme (G5-class) geomagnetic storms of the satellite era, including the 2003 "Halloween" events.

The framework utilizes a Random Forest classifier that generalizes across different instruments, facilitating real-time deployment for space weather monitoring. By identifying these morphologies as ICMEs propagate toward 1 AU, this work provides a scalable diagnostic for anticipating hazards in GEO. Future extensions could potentially apply this framework to near-lunar and Martian regimes to support deep-space exploration.
Poster session day
Wednesday, April 29, 2026
Poster location
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Meeting homepage
2026 Space Weather Workshop
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