Improved Particle Acceleration and Transport in Heliosphere model

An MHD module

- ZEUS code (Clarke, 1996)
- Model the background solar wind
- Inject the CME structure

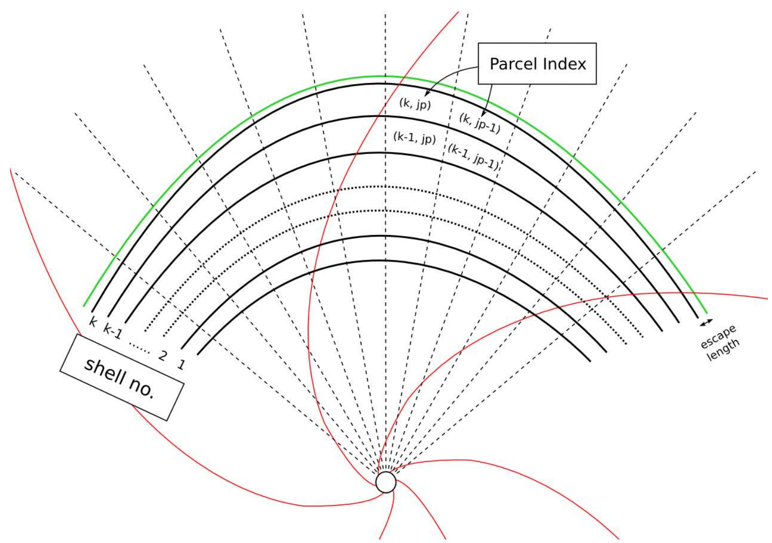
Acceleration module

- Construct a 2D shell model
- Accelerate particles at the shock front
- Diffuse particles in the shock downstream

Transport module

- Based on focused transport equation
- Included cross field diffusion
- Using backward stochastic differential equation method

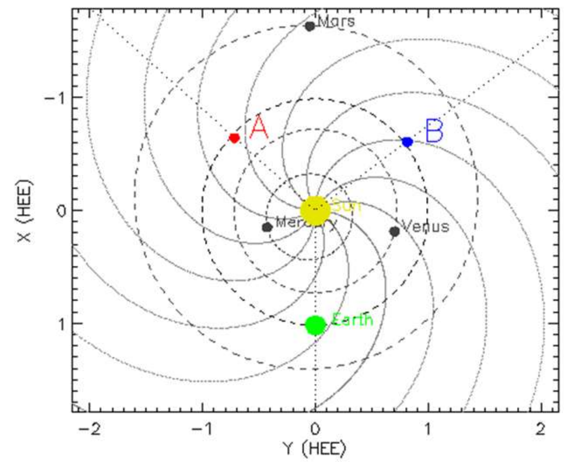
- Accelerated particle distributions are then calculated along the whole shock front, based on the diffusive shock acceleration.
- Accelerated particles are diffused back to the shock complex, between each parcel behind the shock. $\kappa_{\parallel}$ from QLT and $\kappa_{\perp}$ from NLGC.
- The predominant $\kappa_{\parallel}$ is almost along longitudinal direction in the sheath region!
- Thus we have all the distribution functions in each parcel at each time step.
- Important for ESP phase!

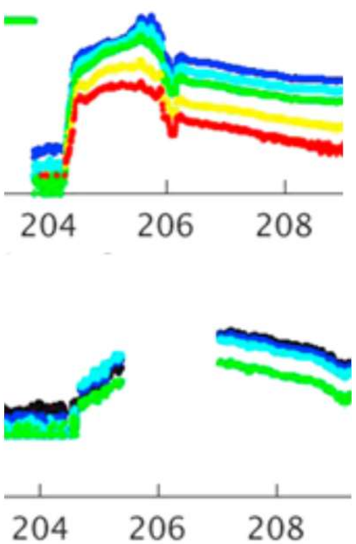


July 23 event

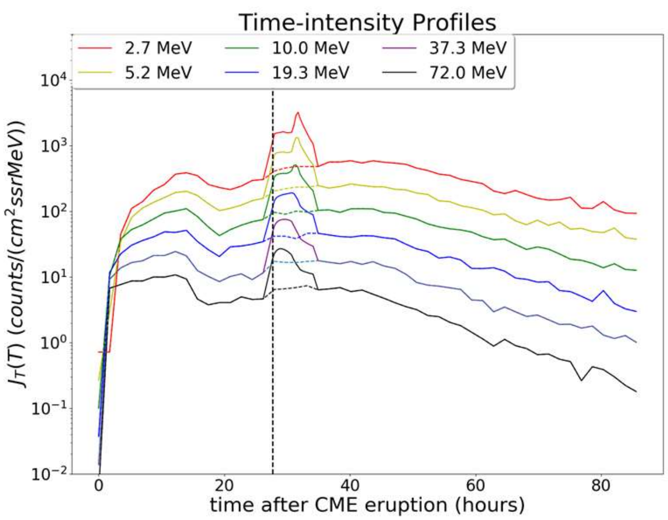
- CME properties:
  - 1900 km/s, 60 degree half width
  - Centered at -165 HEEQ

- Difficulties in this event:
  - Modeling the ESP and decaying phase

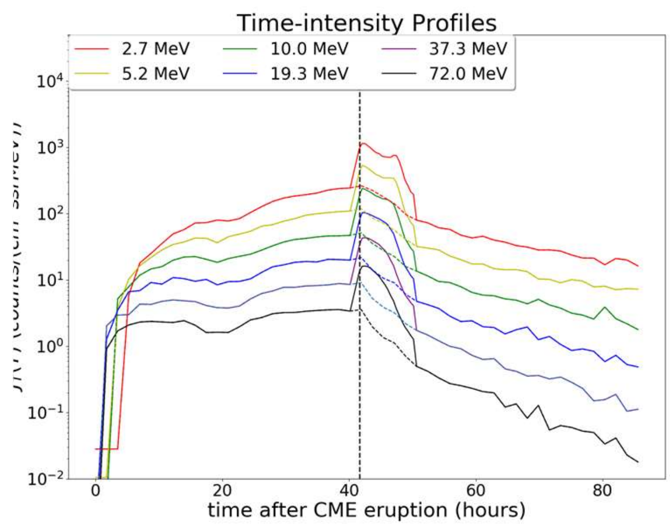




(Luhmann 2018)



STEREO-A

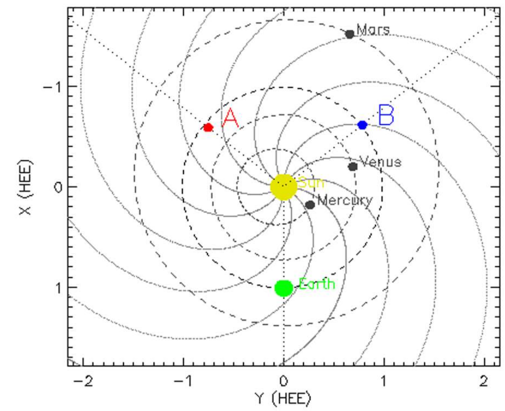


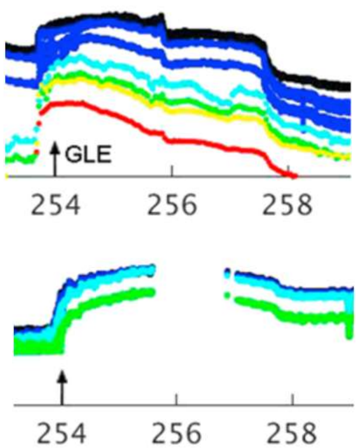
Mars

Sep 10 event

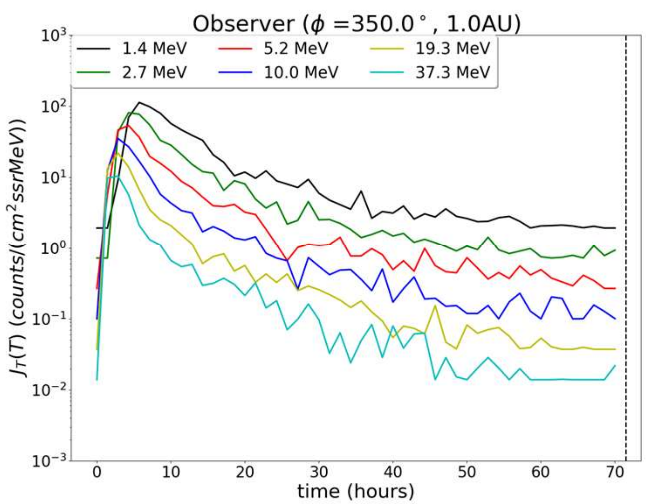
- CME properties:
  - 2500 km/s, 70 degree half width
  - Centered at +108 HEEQ
  - Low background density: 1 per cc at 1 AU

- Difficulties in this event:
  - How to capture the effect from previous event?
  - Perpendicular diffusion to mars

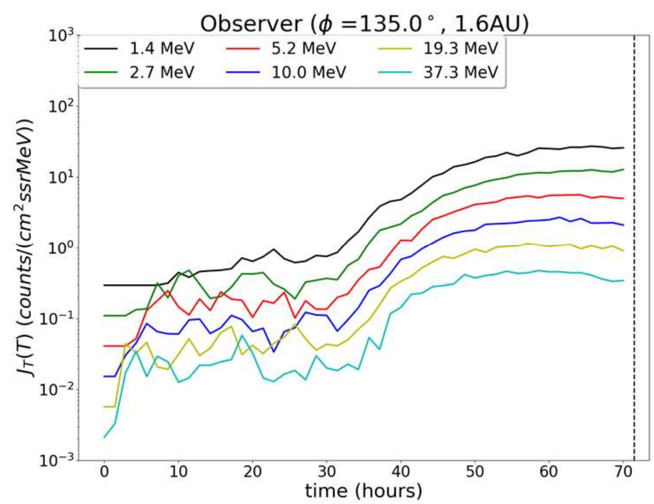




(Luhmann 2018)



Earth



Mars

SUMMARY

- How to optimize run results differ from the initial run?
  - Find the proper solar wind properties (B, n, V)
  - Find the proper CME properties (speed, width, direction) – Ensemble modeling
  - Determines the injection rate from an initial run, then modify the injection rate from the first run.

- What aspects of the event does your model capture well, and what aspects were more difficult to capture?
  - \+ Captures the coupled effect of acceleration and transport. Good for understanding the physics n the SEP events
  - \+ Including perpendicular transport, with $\kappa_\perp$ calculated from NLGC theory. This allow us to have a wide spread of energetic particles over a large longitudinal range.
  - \+ ESP phase and decaying phase can be approximated
  - – Simple homogeneous parker spiral background solar wind
  - – Hard to capture the effect from a previous CME event

- What are the next steps for your modeling technique?
  - Couple with a coronal model for early time accelerations
  - Use real solar wind input for background solar wind
  - Practice modeling on real events.