COLLEGE OF SCIENCE
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Research Horizons Day & Research Week April 11-14, 2017

Research Horizons Day

Radial and Longitudinal Extent of SEP Radiation Environment: Modeling Gradual SEP Events with iPATH

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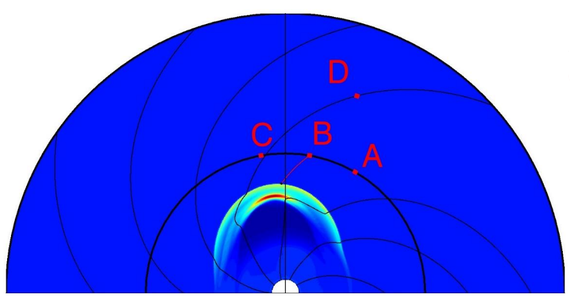
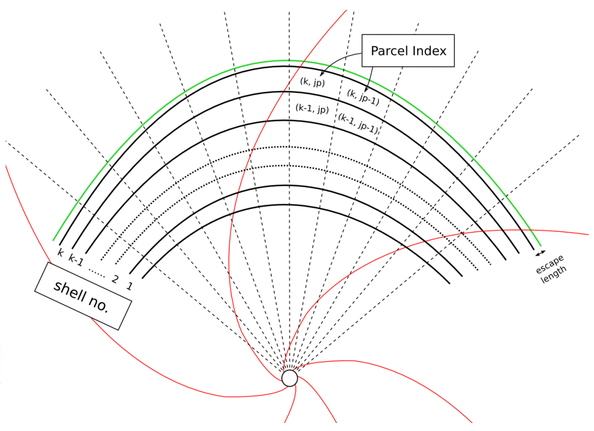
Introduction

- Coronal mass ejections (CMEs) and solar flares are arguably the two most energetic phenomena in the solar system. They are regarded as the sites of Solar Energetic Particle (SEP) events.
- The PATH(Particle Acceleration and Transport in Heliosphere) model, first introduced in Zank et al.(2000), is based on the diffusive shock acceleration(DSA) mechanism.
- We extend the earlier 1D PATH model to study particle acceleration at a 2D CME-driven shock and the subsequent transport. This improved PATH model is named iPATH.
- The development of iPATH is in part stimulated by the need for a realistic and robust tool for space weather SEP forecasting.

Model Overview

- To properly interpret SEP observations, we extended PATH model from 1D to a 2D version. It consists of three parts:
- A MHD module – We use ZEUS3D(Clarke, 2010) code to model the background solar wind as well as the CME-driven shock.

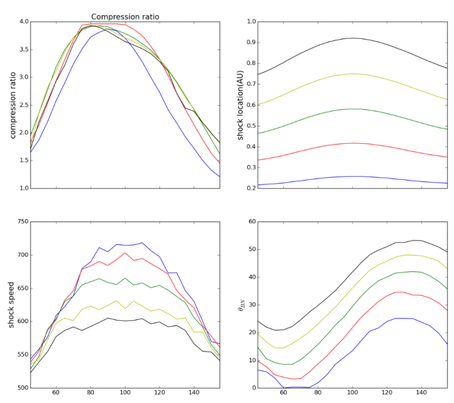


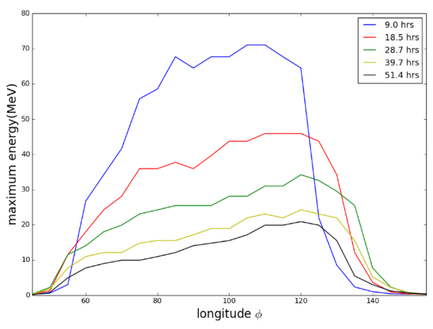


- The particle acceleration module – an improved 2D shell model to follow the acceleration of particles at the shock front and their diffusions in the downstream of the shock;
- The backward particle transport module – a Monte-Carlo code to track the propagation of quasi-particles. The transport process is governed by focused transport equation(FTE).
- Perpendicular diffusion is introduced from the NLGC theory.

Results

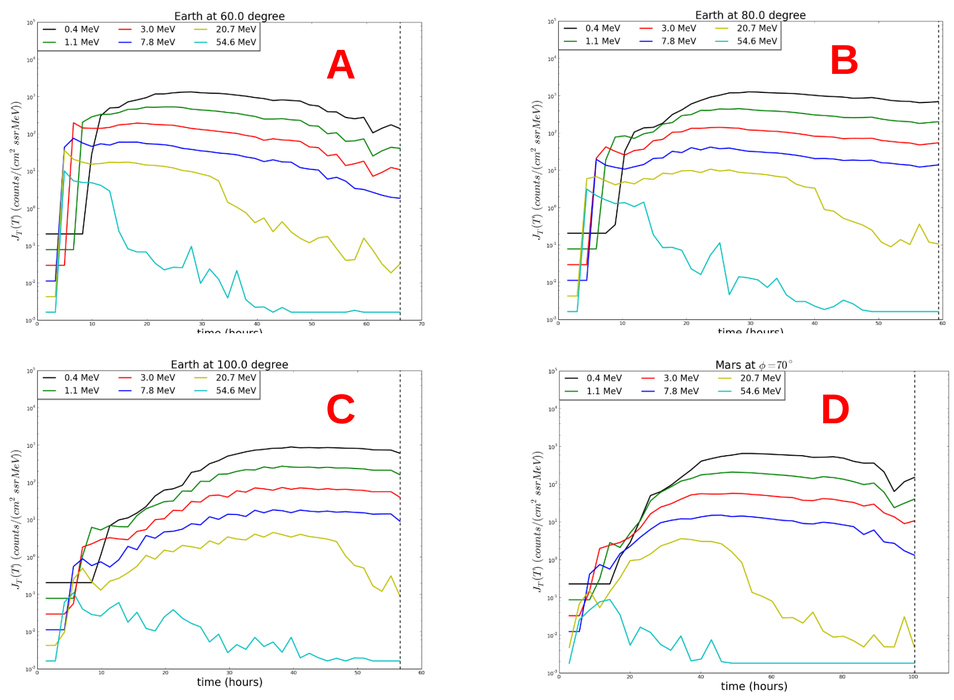
- Shock parameters are followed at each time step.
- Injection and maximum energies for the diffusive shock acceleration(DSA) are then decided:



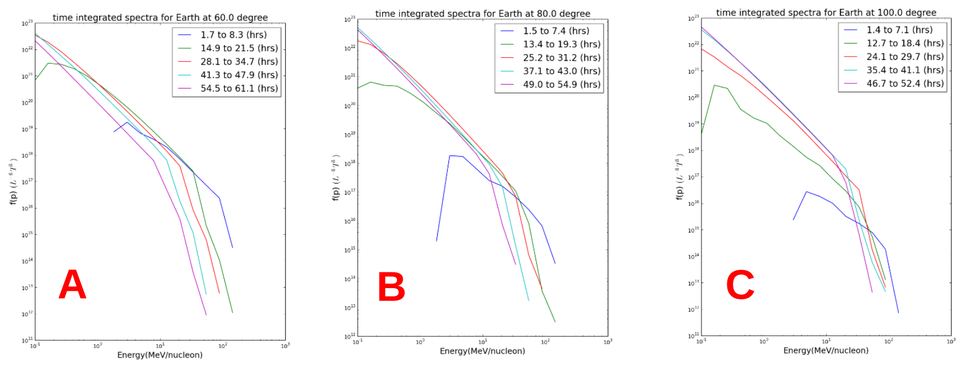


Maximum energy that protons can be accelerated to along the shock front

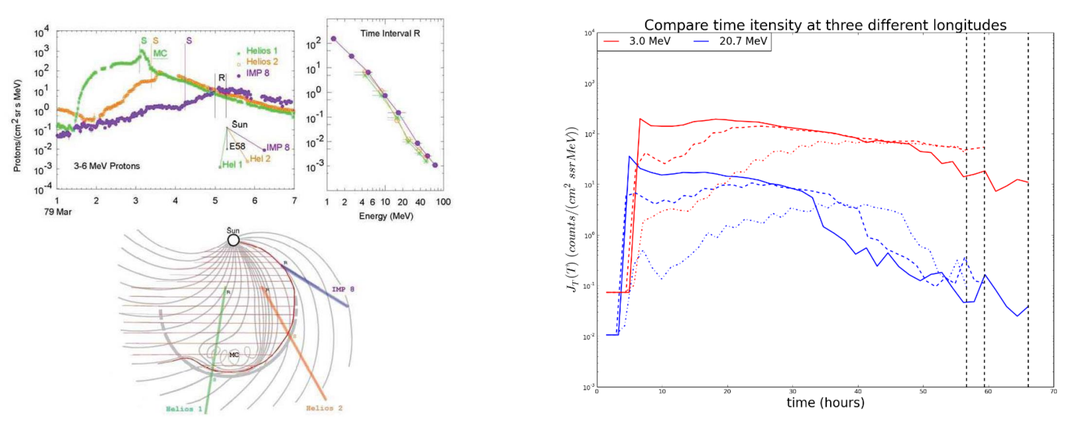
- We plot the time intensity profiles at four sample points.
- This configuration may correspond to simultaneous observation from ACE, STEREO-A/B, and MAVEN spacecraft.



- We can also plot the proton energy spectra for different time interval at different locations.



- Our result agrees with the Reservoir Phenomenon:



Summary

- The major improvement of iPATH is that it models particle acceleration and transport in 2D, therefore yielding a longitudinal dependence of all physical quantities.
- The simulation shows that the shock parameters can vary significantly along the shock front, as well as in the radial direction.
- The perpendicular diffusion is considered both in the acceleration and transport process. As a result our simulation shows the reservoir phenomenon, which is consistent with observations.

Acknowledgements

Use of ZEUS-3D, developed by D. Clarke at the ICA (www.ica.smu.ca) with support from NSERC, is acknowledged. This work is supported by NSF grants ATM-0847719 and AGS-1135432 and an 2013-2014 IIDR grant at UAHuntsville.

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