Title:
"Progress Towards Developing a Self-Consistent Model for the Production and Transport of SEPs by CME-Driven Shocks"

Authors:
I. I. Roussev, I. V. Sokolov, V. Tenishev, and T. I. Gombosi

E-mails:
iroussev@umich.edu, igorsok@umich.edu, iroussev@umich.edu, igorsok@umich.edu, vtenishe@umich.edu, tamas@umich.edu

Affiliation:
Department of AOSS, University of Michigan, 2455 Hayward Street, Ann Arbor, MI 48109-2143, USA; Phone: (++1 734) 647-9689, Fax: (++1 734) 647-3083

Abstract:
Coronal Mass Ejections (CMEs) play a major role in the Sun-Earth connection. The shock waves driven by the ejecta can accelerate charged particles to ultra-relativistic energies as the result of Fermi acceleration processes.

From the perspective of space weather, CMEs and the solar energetic particle (SEP) events associated with them are of particular importance since they endanger human life in outer space and pose major hazards for spacecraft in the inner solar system. The most efficient particle acceleration takes place near the Sun, and the fastest particles can escape upstream of the shock wave, reaching the Earth shortly after the initiation of the CME.

Our ongoing research efforts target fundamental features of gradual SEP events, such as formation and evolution of realistic CME-driven shocks, particle injection at the shock, excitation of turbulence by the self-generated Alfvén waves, particle diffusion due to the enhanced turbulence, and particle escape upstream of the shock, among other phenomena. Our approach is to integrate the best theories developed for every aspect of the SEP production and transport problem, including a realistic model of turbulence near the shock front and effects of SEP spectrum anisotropy. The strength in this integrated approach is that it enables us to quantify the particle acceleration and scattering by the self-excited Alfvén turbulence, and particle transport along and across the interplanetary magnetic field. The excited turbulence is responsible for both the ion acceleration and the shock wave structure.

In this talk, we present a coupled model that describes the low-frequency plasma turbulence and the SEP acceleration and transport. For simplicity, we use the quasi-linear theory to evaluate the growth rate of the turbulent waves, and the particle motion is described in the diffusive approximation. The effects taken into account are: realistic evolution of the shock wave front, advection of the magnetic field in realistic solar wind model, first-order Fermi acceleration for supra-thermal ions, and a self-consistent description of the self-excited Alfvén turbulence and the particle scattering at this turbulence. In the long run, we are committed to developing a predictive capability of the SEP threat related to robotic and human exploration missions. This talk summarizes the progress made in accomplishing this goal.