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The Theory of SEP Acceleration and Transport

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Solar energetic particles (SEPs) are a major constituent of the inner heliosphere during "Solar Maximum" conditions. SEPs occur in two basic classes of events. "Gradual"events are large, infrequent, last for days, are proton-rich, and are associated with coronal mass ejections (CMEs) and type II radio bursts. "Impulsive" events are small, frequent, last for hours, are electron-rich, and are associated with type III radio bursts. Both classes originate in flares/active regions at the Sun. However, gradual events are accelerated over an extended region in longitude, latitude and radial distance. Acceleration at shocks driven by CMEs best accounts for the observed characteristics of gradual events, whereas acceleration in solar flares at sites of magnetic reconnection, either by stochastic acceleration or reconnection-driven shocks, best accounts for impulsive events. It must also be emphasized that the observed temporal, spatial and energy spectral structure of these events is strongly influenced by particle transport in the solar wind. This presentation addresses the theory of shock acceleration as applied to gradual events, including the basic elements of first-order Fermi and shock drift acceleration, wave excitation (which enhances the efficiency of shock acceleration), the effect of shock obliquity, the nature of injection, and the escape of particles upstream of the shock. The presentation also addresses the basic mechanisms of reconnection-associated acceleration including stochastic (second-order Fermi) acceleration. The theory of particle transport in the corona and solar wind will be presented briefly, including the determination of the diffusion tensor. Special attention will be devoted to the origin, energy spectra and transport of SEPs at ground-level-event (GLE) energies. Finally, outstanding challenges for the theory of SEP acceleration and transport are addressed including seed particle injection rates, acceleration at nearly perpendicular shocks, the origin(s) of extreme variability and large spatial extent in SEP intensity, and the puzzling composition of impulsive events.

Author: Prof. LEE, Martin (University of New Hampshire)

Presenter: Prof. LEE, Martin (University of New Hampshire)

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