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Modeling the releasing and precipitation pattern of solar energetic particles in the solar corona magnetic fields

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We present model calculations of solar energetic particle's (SEP) transport through the complex solar coronal magnetic fields and the subsequent interplanetary space. The corona magnetic fields from 1 to 2.5 solar radius (Rs) are calculated from photosphseric field measurements using the PFSS method and the interplanetary magnetic fields are assumed to be ideal parker spiral with a matching boundary with PFSS at 2.5 Rs. Three-dimensional focused transport equations are solved numerically in the reconstructed coronal magnetic fields and the ideal parker interplanetary fields. All physical processes including focusing, adiabatic cooling, gradient/curvature drift, and diffusions are considered. This model is utilized to study the long-standing wide-spread characteristics in the SEP observations. The model is applied to several solar energetic particle events including a circumsolar event, 2011 November 3, in which SEPs are observed promptly after the solar event eruption by three spacecraft (the twin Solar TErrestrial RElations Observatories (STEREO-A and STEREO-B) and ACE) separated by more than 100° in longitude from each other. Energetic electrons at the energy of 100 keV are injected on the time-dependent coronal mass ejection (CME)-driven shock surfaces. The shock surface locations are determined using a series of multipoint coronagraph observations utilizing the robust technique developed by Kwon et al (2014). The shock surfaces are identified as sharp boundaries in coronagraph images and the time evolution of shocks are fitted using an ellipsoid. The injection efficiency of electrons at the shock surfaces are determined by the ambient electron density, shock Mach number, shock obliquity, shock speed, and shock acceleration time scale calculated using the fitted shock properties. And the acceleration efficiency is treated using the results of a set of hybrid simulations performed by Caprioli and Spitkovsky (2014). The longitudinal distribution of the energetic electrons at two times after the onset of the solar eruption is presented in Figure 1.
The effect of the complex coronal magnetic field structure together with the perpendicular diffusion/meandering of field lines due to the photosphere supergranular motion is investigated. Moreover, different injection scenarios, including the compact solar flare, coronal mass ejection, and extreme ultraviolet wave are examined. This model is also applied to study the nonthermal emissions generated by the collision between the energetic particles and the ambient solar wind plasma. The underlying physics of the observational facts of the long-duration gamma-rays and gamma-rays coming from regions where no solar flares or coronal mass ejections is seen will also be studied.

References:

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Figure 1

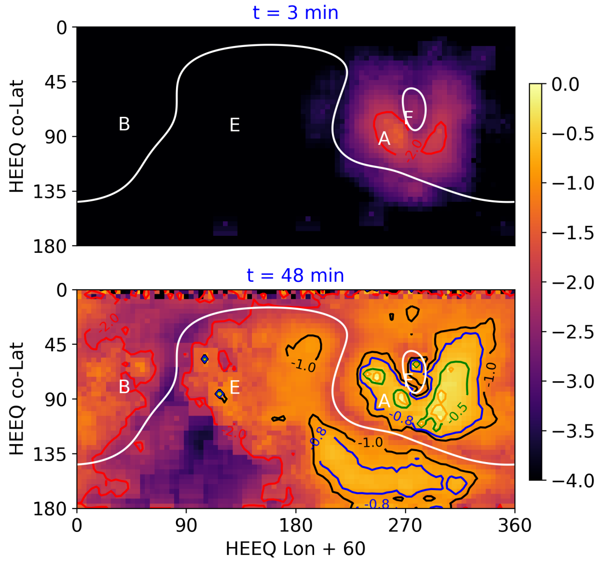

Fig1. Normalized intensity of escaping 100 keV electrons in the log 10 scale on the solar wind source surface 2.5 Rs using observed CME shock as the location of SEP injection.