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Properties of Coronal Shocks During Intense SEP Events and FERMI-LAT γ-ray Events

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We study the spatial and temporal evolution of coronal shock properties inferred from observations to see if they could be the source of the particles producing the γ-rays and the strongest Solar Energetic Particles (SEPs) measured in situ. Greater than 100 Mev γ-rays measured in the minutes to hours following solar flares suggest that high-energy particles interacting in the solar atmosphere can be stored and/or accelerated for long time periods. In the γ-ray study we concentrated on events observed during occulted solar flares. We used a 3D triangulation technique, based on remote-sensing observations to model the expansion of the CME shocks from above the solar surface to the upper corona. Coupling the expansion model to various models of the coronal magnetic field allowed us to derive the time-dependent distribution of shock Mach numbers and the magnetic connection of particles produced by the shock to the solar surface visible from Earth. The reconstructed shock fronts for three γ-ray events became magnetically connected to the visible solar surface after the start of the flare and just before the onset of the >100 MeV γ-ray emission. The shock surface at these connections also exhibited supercritical Mach numbers required for significant particle energization. The strongest γ-ray emissions occurred when the flanks of the shocks were connected in a quasi-perpendicular geometry to the field lines reaching the visible surface. Multipoint, in situ, measurements of SEPs were consistent with the production of these particles by the same shock processes responsible for the γ-rays. Using the observationally-derived shock properties as input parameters to a timedependent diffusive-shock acceleration model we show that during the 17 May 2012 GLE event particles could have been accelerated by the shock to several hundreds of MeVs within minutes of the CME onset.

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