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Simulation of Energetic Neutral Atom Imaging of Solar Energetic Particles

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Energetic Neutral Atoms (ENAs) provide the only way to observe solar energetic particles (SEPs) where they are accelerated. In intense SEP events, the high-energy protons appear to be accelerated by the fast CME driven-shock mostly at altitudes of $\sim$1.5 to tens of Rs, while the low-energy protons are continuously produced as the shock propagates outward, even near 1 AU. These protons can charge exchange with the ambient solar wind or interstellar neutrals to become ENAs. Assuming a CME-driven shock propagates from 1.5 to 40 Rs with a constant speed of 1800 km/s and compression ratio of 3.0, we simulate the accelerated SEPs and the corresponding ENAs originating from these SEPs via various charge-exchange interactions. We also calculate their survival probabilities to reach 1 AU. To reproduce the STEREO ENA fluence observations at $\sim$2-5 MeV/nuc (Mewaldt et al., 2009) requires that the accelerated protons are effectively trapped downstream of the shock. We find that ENAs above $\sim$100 keV arriving at 1 AU mainly originate from the source below 5 Rs, whereas most of the ENAs below $\sim$20 keV originate from above 10 Rs. We also estimate the flux of ENAs coming from the charge exchange of the energetic storm protons (ESPs), accelerated by the fast CME-driven shock near 1 AU, with interstellar hydrogen and helium, using the WIND/3DP ESP measurements. These simulations/estimates suggest that suitable instrumentation would be able to detect ENAs from SEPs, and to even make images of where ENAs and correspondingly SEPs, are being produced as a function of energy.