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Observations and simulations of decay phases of Solar Energetic Particle events

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The properties of solar energetic particle (SEP) event profiles have been researched extensively to investigate the acceleration and transport of SEPs. The effects on SEP intensity profiles of particle-filled magnetic flux tubes corotating with the Sun are generally considered to be negligible. However, corotation has recently been suggested to have an effect on SEP decay phases, based on results of test particle simulations. This is expected to be dependent on the location of the observer with respect to the active region (AR) associated with the event.

To determine if corotation effects are discernible in observations, we analyse multi-spacecraft observations of SEP intensity profiles from 11 events between 2020 and 2022, using data from Solar Orbiter, Parker Solar Probe, STEREO-A, and SOHO. We also aim to study how the properties of the flares and coronal mass ejections (CMEs) associated with the events affect the parameters of the decay phase.

Using 3 energy channels; electrons $\sim$1 MeV, protons $\sim$25 MeV, and protons $\sim$60 MeV, we derive the decay time constant, τ, and study the dependence of τ on the longitudinal separation, $\Delta\phi$, between the source active region and the spacecraft's magnetic footpoint on the Sun.

We find that within individual events there is a tendency for τ to decrease with increasing $\Delta\phi$: test particle simulations show that this is a signature of corotation, not present when the latter is neglected. Thus we conclude that corotation has an effect on the decay phase of an SEP event and should be included in simulations and interpretations of these events.

We characterise the magnitude of the solar event that produced the SEPs using the intensity of the associated flare, speed of the associated coronal mass ejection and SEP peak flux as proxies. Our results show that the magnitude of the solar event influences the measured τ values and are likely the cause of the observed large inter-event variability, along with varying solar wind and interplanetary magnetic field conditions.

Further we introduce a new methodology to incorporate turbulence-induced perpendicular scattering within 3D test particle simulations in an approximate way. At randomly generated times the particle's position is displaced in the direction perpendicular to the interplanetary magnetic field according to a prescribed distribution. We compare the results of simulations including this implementation of perpendicular scattering with those that neglect it, with emphasis on differences in the decay phase and on how corotation effects vary between the two types of simulations.

Collaboration(s)

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