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Large scale hybrid simulations of solar energetic particle acceleration in gradual CME events

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We use a massively parallel 3D hybrid particle code, dHybrid, to simulate the corona environment and the acceleration mechanisms of Solar Energetic Particles. The simulations describe a CME structure propagating at speeds of up to 1000 km/s interacting with the slower solar wind.

This interaction causes the formation of a large scale quasi-parallel shock structure due to the expanding CME and the solar wind embedded magnetic field. The interaction region simulated is the outer coronal environment with the location and acceleration mechanisms of high energy particles studied.

The simulation results support a surfatron-like acceleration model as the mechanism responsible for the most energetic ions in the early acceleration phase. Particles are not observed to cross the shock front several times, as it is required by Fermi acceleration mechanisms. Instead, our results show that particles crossing the shock front accelerate perpendicularly to the shock front while maintaining their parallel velocity.

The interaction between a faster CME and slower one is a particularly interesting scenario as these events are well correlated with the production of solar energetic particles. Our results show whistler and magnetoacoustic waves developing due to the first shock front, which are responsible for the electric field structure observed, allowing the surfing acceleration mechanism to occur. In this kind of configuration the importance of the proposed acceleration model as a means of providing a seed particle population is studied.