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Electron pre-acceleration at oblique collisionless shocks

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We discuss nonthermal electron acceleration mechanisms at quasi-perpendicular shocks, for which substantial progress has been made in recent
years. Thermal electrons have gyroradii many orders of magnitude smaller than the finite width of a shock, thus need to be pre-accelerated before they can cross it and be accelerated by diffusive shock acceleration. One region where pre-acceleration may occur is the inner foreshock, which upstream electrons must pass through before any potential downstream crossing. We report on large scale particle-in-cell simulations that generate a single shock with parameters motivated from supernova remnants. Within the foreshock, reflected electrons excite the oblique whistler instability and produce electromagnetic whistler waves that quickly evolve into non-linear structures. Although these non-linear structures do not in general interact with co-spatial upstream electrons, they resonate with electrons that have been reflected at the shock. We show that they can scatter, or even trap, reflected electrons, confining around 0.8% of the total upstream electron population to the region close to the shock where they can undergo substantial pre-acceleration. This acceleration process is similar to, yet approximately 3 times more efficient than, stochastic shock drift acceleration. We shall also comment on the role of pre-existing turbulence in the upstream medium and on particular aspects of shocks associated with neutron-star mergers.

Primary author: POHL, Martin

Presenter: POHL, Martin