Nonlinear particle reacceleration by successive shocks

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Star forming regions host clusters of hundreds of massive stars. It is expected that in such environments multiple supernovae explode successively within small timescales and reaccelerate cosmic rays.

After the passage of a few shocks, the energy density of the particles becomes comparable to that of the shocks and the backreaction of the cosmic ray pressure onto the shocks must be taken into account.

We develop a nonlinear semi-analytical model of particle reacceleration at shock waves. We solve the kinetic equation for the particles together with the momentum equation for the flow profile. The injection of particles from the thermal bath is self-consistently accounted for using the thermal leakage injection mechanism and we account for the resonant excitation of Alfvén waves in the upstream region.

We found that a nearly universal asymptotic solution is obtained after the passage of a few shocks. The high energy component of this solution does not depend on the injection efficiency, nor on the Mach number of the shock.

The downstream pressure of cosmic rays saturates at the level of a few percents of the shock ram pressure, for any injection efficiency.