Time Variability and Bifurcations of Cosmic Ray Acceleration at Shocks*

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Dynamics of shock acceleration of ultrarelativistic particles is analyzed with the emphasis on the backreaction of such particles on the shock parameters. To this end, a complete kinetic description of accelerated particles coupled with the plasma flow around a shock, is reduced to a tracktable system of time dependent integro-differential equations. A well known multiplicity [1] of stationary solution of the original kinetic system is recovered. A sequence of bifurcations in acceleration process which results from growing maximum momentum of accelerated particles is described. In addition to the already known pitchfork bifurcation to a bistable shock structure, a Hopf bifurcation to a limit cycle is found. Thus, the route to rapid variability of the acceleration process is suggested. A possible relation of this variability to the recent observations of the supernova RXJ 1713 is discussed [2].

The upstream turbulence driven by accelerated particles is studied. The possibility of formation of multiple shocks (shocklets) in the cosmic ray shock precursor is demonstrated by obtaining a traveling wave solution. The heating of the upstream plasma by the shocklets is calculated. These processes are shown to be critical for obtaining the acceleration efficiency and can significantly enhance the acceleration rate [3, 4]. Since the shocklets are driven by accelerated particles themselves, they provide an important feedback loop in a self-regulation mechanism of the entire acceleration process.

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References