COSMIC RAY ACCELERATION IN THE PRESENCE OF LOSSES

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Diffusive Fermi acceleration on hydromagnetic shock fronts (Axford et al., 1977; Bell, 1978a,b; Blandford and Ostriker, 1978) is a fairly slow process: most scatterings are energetically neutral, only those across the velocity jump yield a first order acceleration. Thus energy losses of cosmic rays (CR) due to e.g. adiabatic cooling, ionising, Coulomb-, or nuclear collisions, bremsstrahlung, synchrotron radiation, should play a role in limiting the acceleration, since most shocks are coupled with a loss region (HII regions, SNR's, galactic density wave, stellar wind shocks). In addition, for this process to be a local one in the galaxy, the magnetic irregularities must either be excited by the accelerated CR's or produced by a downstream source. This implies a finite wave build-up time during the shock life time. Nevertheless, in the loss free case, the time-asymptotic amplification is independent of the mean free path λ (or the diffusion coefficient κ) which only appears in the spatial scale for the CR intensity. To investigate the effects of losses, the CR diffusion equation is amended by a simple loss term f/τ, with an (energy dependent) loss time τ, f being the CR momentum distribution. For τ spatially homogeneous, a distributed source is required. Then acceleration is only effective if $X \equiv 4\kappa/V_s^2 \cdot \tau \lesssim 1$, i.e. if the acceleration time $t_{acc} = 4\kappa/V_s^2$ is smaller than τ, on <u>either</u> side of the shock. As the Figure shows, also the spatial intensity profile is modified. Wave excitation in dense clouds is prohibitive (Cesarsky and Völk, 1978). Even in a "warm" ($T \sim 10^4$K) intercloud medium shock speeds $V_s \gtrsim 3 \times 10^7$ cm/sec are required to accelerate mildly relativistic particles. Waves from an upstream source (star) inside clouds should frictionally dissipate after distances $L \lesssim 5 \times 10^{14}$ cm << λ (10 MeV) if a solar wind scaling is adopted. Thus, presumably in such a case there is no acceleration of stellar or shock-injected particles through a stellar wind shock by scattering within the cloud, but possibly by reflection from beyond the cloud, the condition being $l/\tau \cdot V_s \lesssim 1$, where l is the linear cloud size. Diffusive approach from outside to a standing shock (Jokipii, 1968) appears to be very energy-selective, even in a loss free medium.

Extended SN shocks in a hot medium appear very efficient accele-

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rators. However the waves are subject to severe nonlinear Landau damping (Lee and Völk, 1973). Neglecting trapping of thermal ions (Kulsrud, 1978), this leads to a wave cutoff resulting in strongly suppressed acceleration below that particle momentum where the CR intensity turns down to a spectrum less steep than p^{-2} thus possibly requiring injection from behind. Also t_{acc} exceeds the typical SN life time of 8×10^5 yr. for energies beyond about 10 GeV in this limiting case.

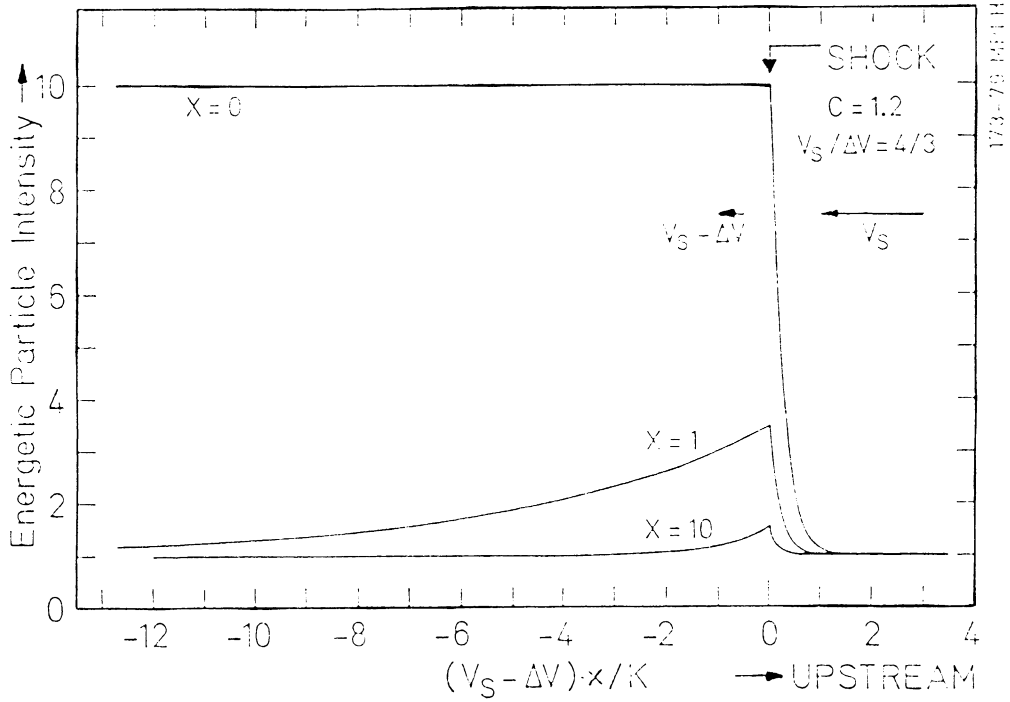

Figure: Relative intensity vs distance in units of $\kappa/V_s - \Delta V)$ near a strong shock. A power law source $\sim p^{-3C}$ is assumed. $X = 4\kappa / V_s^2 \tau$, for various uniform loss rates $1/\tau$.

References

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