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Implications of shock acceleration theory for gamma-ray burst prompt emission

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Abstract. Most recent models of gamma-ray bursts consider a relativistic blast wave, emanating from a massive stellar progenitor and expanding into the surrounding int erstellar medium, as the site for their activity. The popular perception is that the optical and radio afterglows result from the external shock interface, while the prompt transient gamma-ray signal arises from multiple shocks internal to the expansion. This paper illustrates a number of acceleration properties of relativistic shocks that pertain to GRB models and interpretation of the BATSE/EGRET data, by way of a standard Monte Carlo simulation. Computations of the spectral shape, the range of spectral indices, and the energy gain per shock crossing are presented, as functions of the shock speed and the type of particle scattering. It is apparent that while parallel shocks can efficiently accelerate particles, and these environments resemble those expected in GRB internal shocks, perpendicular ones cannot unless the particle diffusion is almost isotropic, i.e. close to the Bohm limit. Since the external GRB shock wave is effectively perpendicular nearly everywhere, the positive EGRET detections of bursts can be readily interpreted along two lines: (i) that the hard gamma-ray emission arises from mildly-relativistic internal shocks of varying field obliquities, generating a spread in EGRET spectral indices, or (ii) that a tiny quasi-parallel portion of the external shock is responsible for gamma-ray bursts. As the latter alternative forces dramatic enhancements of the burst production rate, the association of prompt emission with internal shocks may prove more plausible.