Modelling of particle acceleration at relativistic shocks

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Abstract

The interaction of relativistic plasmas with shock waves leads to the generation of particles with energies exceeding the strength of the magnetic fields in the shock front. The acceleration process is different from the classical Fermi acceleration mechanism. In this paper, we present a model for the acceleration of particles at relativistic shocks. The model is based on the assumption that the particles are accelerated by the magnetic field fluctuations. The model predicts a significant enhancement of the particle energy distribution at relativistic shocks.

1 Introduction

At a relativistic shock wave, the bulk velocity of the flow is comparable to the particle velocity. This leads to an increase of particle energy due to the ponderomotive force. In contrast to the non-relativistic case, the particle distribution function is different at the shock, including the spectrum and amplitude of the magnetic field fluctuations. The model predicts a significant enhancement of the particle energy distribution at relativistic shocks.

2 Simulations

The simulations test the model by calculating the particle energy distribution at relativistic shocks. The simulations show that the particle distribution function is different at the shock, including the spectrum and amplitude of the magnetic field fluctuations. The model predicts a significant enhancement of the particle energy distribution at relativistic shocks.

3 Results

Oblique sub-relativistic shocks

The particle spectra for the sub-relativistic (\( \gamma < 1 \)) shock waves are shown in Fig. 1. The following features are visible:

- The particle spectra are not monotonically increasing in a full energy range.
- The spectrum shows a handlebar shape at low energies.
- The spectrum shows a broad peak at high energies.

Oblique super-relativistic shocks

The particle spectra for the super-relativistic shocks are shown in Fig. 2. The following features are visible:

- The particle spectra are not monotonically increasing in a full energy range.
- The spectrum shows a handlebar shape at low energies.
- The spectrum shows a broad peak at high energies.

Parallel shocks

In Fig. 3, we present particle spectra for the parallel shock waves. The following features are visible:

- The particle spectra are not monotonically increasing in a full energy range.
- The spectrum shows a handlebar shape at low energies.
- The spectrum shows a broad peak at high energies.

References