ON THE NATURE OF MAGNETOHYDRODYNAMIC TURBULENCE IN THE INTER-STELLAR MEDIUM

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ABSTRACT. Various mechanisms of creation of the extended spectrum of MHD turbulence in the interstellar medium are reviewed. Within the scales 10^{14} cm $\lesssim L \lesssim 10^{19}$ cm the turbulence mostly consists of the ensemble of weak shock waves. At 10^{12} cm $\lesssim L \lesssim 10^{14}$ cm the principle mechanism is generation of MHD waves by cosmic rays.

Observations of cosmic rays (CRs) give us evidence that in the interstellar medium (ISM) there exists an extended spectrum of MHD turbulence within the scales 10^{12} cm $\lesssim L \lesssim 10^{19}$ cm. A plausible explanation of this is a turbulent cascading of strong, large-scale motions, observed in the Galaxy (see e.g. McIvor, 1977). However, in the hot phase of the ISM ($T \sim 10^6$ K, $n \sim 10^{-2}$ cm^{-3}) this mechanism fails because of collisionless damping. Bykov and Toptygin (1987) proposed an idea that in the hot ISM strong shocks from supernovae collide with multiple dense clouds and excite weaker, multiple shocks. The latter form a supersonic turbulence within the scales 10^{12} cm $\lesssim L \lesssim 10^{19}$ cm with the spectrum $W(k) \sim k^{-2}$. This provides a diffusional propagation of CRs at energies 1 GeV $< E \lesssim 10^6$ GeV with a diffusion coefficient $D(E) = \mathrm{Const}(E) \sim 10^{29}$ cm^2/s. However, at low energies ($E \sim 1-100$ GeV) another mechanism can be at work, viz. the CR-generated turbulence (see e.g. Wentzel, 1974).

Here I present basic results of the calculation of the Alfvén-wave turbulence spectrum $W(k)$ within the context of the latter mechanism. For details see Fedorenko et al. (1987) and Fedorenko et al. (1988). We find $W(k)$ from some nonlinear, stationary wave equation:

$$\Gamma_{nl}(k) = \Gamma_{ql}(k) \tag{1}$$

where $\Gamma_{ql}(k)$ is a quasilinear CR-generation increment, $\Gamma_{nl}(k)$ - decrement, calculated in Fedorenko et al. (1988), taking into account nonlinear wave-particle interactions. From eq. (1) we found:

$$W(k) \sim k^{\gamma-4} \tag{2}$$

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with γ being the differential CR energy spectrum index. With $\gamma = 2.5$ we obtain from eq. (2) $W(k) \sim k^{-1.5}$, which is compatible with CR observations. The calculated level of the turbulence also agrees with the observational restrictions. Solution (2) is valid at 10^{12} cm $\lesssim L \lesssim L^*$ where L^* depends on the rate R of the CR scattering on the shock-wave ensemble in the hot ISM. If $R \sim 10^{-9}-10^{-8}$ s^{-1}, then $L^* \sim 10^{14}-10^{15}$ cm. Therefore, the CR-generated turbulence governs the CR diffusion at energies 1 GeV $\lesssim E \lesssim$ 100 GeV with $D(E) \sim E^{0.5}$.

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