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Equilibrium velocity distributions in Alfvenic turbulence and "apparent" temperature
アルフェン乱流中の平衡分布と「見かけの」温度

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In this presentation, the equilibrium velocity distribution in parallel propagating Alfvenic turbulence is presented. The "apparent temperature" due to the non-resonant ion heating is explained on the basis of the equilibrium velocity distribution.

1. Introduction and Result

In this presentation, we report our recent results on "Alfvenic" equilibrium velocity distributions in collisionless plasmas[1-2]. In the present proceeding, a simple equilibrium distribution related to the nonresonant "pseudo-" heating is presented.

We briefly discuss the Sonnerup-Su solution, which is an *exact* Alfven wave solution of the Vlasov-Maxwell system[3]. We here assume that all the physical quantities depend only on one spatial coordinate (x). The velocity distribution functions (f) obey the Vlasov equation

$$\frac{df}{dt} = \frac{\partial f}{\partial t} + v_x \frac{\partial f}{\partial x} + \frac{d\mathbf{v}}{dt}\cdot\nabla_v f = 0, \qquad (1)$$

where $\mathbf{v}=(v_x, v_y, v_z)$,

$$\frac{d\mathbf{v}}{dt} = \frac{q}{m}(\mathbf{e}+\mathbf{v}\times\mathbf{b}), \qquad (2)$$

$\mathbf{e}=(e_x, e_y, e_z)$, $\mathbf{b}=(b_x, b_y, b_z)$. We here assume $e_x=0$, and $b_x=B_0=const.$ When a monochromatic wave ($b = b_0 \exp(-i\varphi_k)$, where $\varphi_k = \omega t - kx$, b_0, ω, and $k=const.$) is given, there are two constants of motion[1-4]

$$\left(v_\varphi m v_x - \frac{m v_x^2}{2}\right) + \frac{q}{k}\mathbf{v}\cdot\mathbf{b} \equiv H, \qquad (3)$$

$$\frac{m}{2}\left((v_x - v_\varphi)^2 + v_y^2 + v_z^2\right) \equiv E. \qquad (4)$$

The Sonnerup-Su solution $f(x,\mathbf{v},t)=f(\alpha H + \beta E)$ is an exact solution of (1), where α, β are the constants which satisfy the conditions[1-3]. Remark that the solution is exact even in plasmas with finite temperature. In the entropy-maximized form, the Sonnerup-Su can be written as a bi-Maxwellian distribution with the oscillating bulk velocity[1]. When we consider the nondispersive waves in the low-frequency limit, the Sonnerup-Su solutions can be extended to those of incompressible Alfvenic turbulence with the broadband spectrum[2],

$$f = A\exp\left[-\frac{v_x^2 + (v_y - cb_y)^2 + (v_z - cb_z)^2}{v_{th}^2}\right], \qquad (5)$$

where $A = n_0/(\sqrt{\pi}^3 v_{th}^2)$, v_{th} is the thermal velocity, $b = \sum b_k \exp(-i\varphi_k)$, $c = -v_\varphi / B_0$, respectively. We here assume $u_x=0$.

The distribution (5) directly gives the "apparent temperature"[2]

$$T_{A\perp} = \int \frac{m(v_y^2 + v_z^2)}{2} f d\mathbf{v} = n_0 k_B T\left(1 + \frac{v_\varphi^2}{v_{th}^2}\frac{|b|^2}{B_0^2}\right), \qquad (6)$$

which is equivalent to the past work by Wang et al.[5], in which the nonresonant ion heating in Alfvenic turbulence was firstly demonstrated. The result merely shows that the nonresonant ion heating in Alfvenic turbulence is a relaxation process to "Alfvenic" equilibrium state. Remark that the distribution is a mechanical equilibrium and the ionizations and collisions in the solar atmosphere, the chromospheric and coronal plasmas may play an important role in increasing the physical entropy.

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