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Dust heating by Alfvén waves using non-Maxwellian distribution function

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Quasilinear theory is employed in order to evaluate the resonant heating rate by Alfvén waves of multiple species dust particles in a hot, collisionless, and magnetized plasma, with the underlying assumption that the dust velocity distribution function can be modeled by a generalized (r, q) distribution function[1]. The kinetic linear dispersion relation for the electromagnetic dust cyclotron Alfvén waves is derived, and the dependence of the heating rate on the magnetic field, mass, and density of the dust species is subsequently investigated. The heating rate and its dependence on the spectral indices r and q of the distribution function are also investigated. It is found that the heating is sensitive to the negative value of spectral index r.

We numerically investigate the expressions for the heating rate and the linear dispersion relation given by Eqs.

$$\frac{1}{T_{\alpha\perp}}\frac{dT_{\alpha\perp}}{dt} = \frac{-8\pi^2 c^2 \Omega_\alpha^2 A_1}{3B_0^2 v_{T\alpha}^2 A_2}\sum_{k>0}\frac{W_k(t)}{k_\parallel}\Bigg\{\left(1+2r-A_2\xi_\alpha\frac{\omega+\Omega_\alpha}{\omega}\right)B_1\xi_\alpha^{2(1-q+r)}\,{}_2F_1\!\left(q+1,q-\frac{1}{1+r},q+\frac{r}{1+r},-\frac{q-1}{\xi_\alpha^{2+2r}}\right)$$
$$+2\xi_\alpha^2\left[1+\frac{q(1+r)}{q-1}\xi_\alpha^{2+2r}\left(1+\frac{\xi_\alpha^{2+2r}}{q-1}\right)^{-1}\right]\left(1+\frac{\xi_\alpha^{2+2r}}{q-1}\right)^{-q}-2(1+r)(q+1)B_1\xi_\alpha^{2(1-q+r)}$$
$$\times\,{}_2F_1\!\left(q+2,q-\frac{1}{1+r},q+\frac{r}{1+r},-\frac{q-1}{\xi_\alpha^{2+2r}}\right)\Bigg\},$$

$$\frac{c^2k_\parallel^2}{\omega^2} = 1-\sum_\alpha\frac{\omega_{p\alpha}^2}{\omega^2}\frac{\omega}{A_2(\omega+\Omega_\alpha)} \times\left[A_1C_1\xi_\alpha+\xi_\alpha^2\mathbf{Z}_1(\xi_\alpha)-\mathbf{Z}_2(\xi_\alpha)\right],$$

respectively. Accordingly, we take some typical plasma parameters that are used to compute the heating rate of the dust particles. Thus, we take[2] $B_0 = 10^4$ G, $n_i = 2\times10^{11}\,\mathrm{cm}^{-3}$, $n_e = 0.5\times10^{10}\,\mathrm{cm}^{-3}$ and $T_0 = 300\circ$K. The heating of dust particles by the Alfvén waves with the power law spectra, depends on the dust species, the spectral power index of the Alfvén waves, usually chosen to be [3] $\gamma_\omega \simeq 1.5-2$. For efficient heating, the resonant factor $R_\alpha = (\omega \pm \Omega\alpha)/(k_\parallel v_{T\alpha}) \approx -1$.

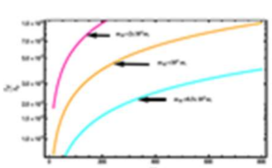

FIG. 1. Heating rate fixed value of r and q, varying mass number m_d.

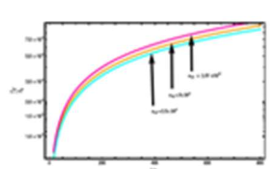

FIG. 2. Heating rate fixed value of r and q, varying number density n_d.

A simple analysis of the linear dispersion relation shows that by increasing masses or the number densities or the charge numbers z_d of the dust particles and magnetic field, the corresponding wavenumber also increases as shown in Fig. 1, 2, 3. For graphical investigation, we plot a graph of the heating rate with a normalized temperature versus normalized time. The temperature is normalized by initial equilibrium temperature, and time is normalized by cyclotron frequency of the dust particles. We have also checked for the dependence of the heating of dust species on the spectral indices r and q, as shown in Fig. 4.

References
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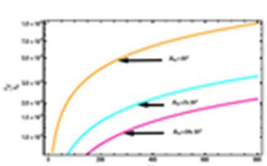

FIG. 3. Heating rate fixed value of r and q, varying magnetic field B.

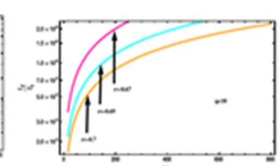

FIG. 5. Heating rate fixed $q = 10$ and varying r.