# Parameter standardization

Definition

$c$ : lightspeed

$m = m_e m^*$

$q = q_e q^*$

$v = cv^*$

$T$ ULF wave period

$x = cTx^*$

$\vec{B} = B_{eq}\vec{B}^*$

$\vec{E} = B_{eq}\vec{E}^*$

$t = Tt^*$

so,

$\frac{\partial B_z}{\partial r} = \xi_r$

$\frac{\partial (B_z^* B_{eq})}{\partial (cTr^*)} = \frac{B_{eq}}{cT}\frac{\partial B_z^*}{\partial r^*} = \frac{B_{eq}}{cT}\xi_r^* = \xi_r$

$\vec{v} = -\{B_z + \frac{mc}{q}(\frac{cE_A \sin\{m2\pi(\frac{t}{T} - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\}}{B_z^2}\xi_r)\}^{-1}(E_A \sin\{m2\pi(\frac{t}{T} - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\} - \frac{\mu}{q}\xi_r + \frac{mc^2}{q}\frac{(E_A \sin\{m2\pi(\frac{t}{T} - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\})^2 \xi_r}{B_z^3})\vec{e_\theta}$

$\vec{v} = -\{B_{eq}B_z^* + \frac{m_e m^* c}{q_e q^*}(\frac{cB_{eq}\vec{E_A^*} \sin\{m2\pi(\frac{Tt^*}{T} - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\}}{(B_z^* B_{eq})^2}\frac{B_{eq}}{cT}\xi_r^*)\}^{-1}(B_{eq}\vec{E_A^*} \sin\{m2\pi(\frac{Tt^*}{T} - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\} - \frac{\mu}{q_e q^*}\frac{B_{eq}}{cT}\xi_r^* + \frac{m_e m^* c^2}{q_e q^*}\frac{(B_{eq}\vec{E_A^*} \sin\{m2\pi(\frac{Tt^*}{T} - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\})^2 \frac{B_{eq}}{cT}\xi_r^*}{(B_z^* B_{eq})^3})\vec{e_\theta}$

$\vec{v} = -\{B_{eq}B_z^* + \frac{m_e m^* c}{q_e q^*}(\frac{\vec{E_A^*} \sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\}}{(B_z^*)^2}\frac{1}{T}\xi_r^*)\}^{-1}(B_{eq}\vec{E_A^*} \sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\} - \frac{\mu}{q_e q^*}\frac{B_{eq}}{cT}\xi_r^* + \frac{m_e m^* c^2}{q_e q^*}\frac{(\vec{E_A^*} \sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\})^2 \frac{1}{T}\xi_r^*}{(B_z^*)^3})\vec{e_\theta}$

$$\vec{v} = -\{B_z^* + \frac{m_e m^* c}{B_{eq} q_e q^*}(\frac{\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\}}{(B_z^*)^2}\frac{1}{T}\xi_r^*)\}^{-1}(\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\} - \frac{\mu}{q_e q^*}\frac{1}{cT}\xi_r^* + \frac{m_e m^* c^2}{q_e q^* B_{eq}}\frac{(\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\})^2\frac{1}{T}\xi_r^*}{(B_z^*)^3})\vec{e_\theta}$$

$\Omega_e = \frac{q_e}{cm_e}B_{eq}$ : Electron cyclotron frequency

$$\vec{v} = -\{B_z^* + \frac{m^*}{\Omega_e q^*}(\frac{\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\}}{(B_z^*)^2}\frac{1}{T}\xi_r^*)\}^{-1}(\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\} - \frac{\mu}{q_e q^*}\frac{1}{cT}\xi_r^* + \frac{m^* c}{\Omega_e q^*}\frac{(\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\})^2\frac{1}{T}\xi_r^*}{(B_z^*)^3})\vec{e_\theta}$$

$$\mu = \frac{mv_\perp^2}{2B} = \frac{m^* m_e c^2 v_\perp^{*2}}{2B^* B_{eq}} = \frac{c^2 m_e}{B_{eq}}\mu^*$$

$$\vec{v} = -\{B_z^* + \frac{m^*}{\Omega_e q^*}(\frac{\vec{E_A^*}}{(B_z^*)^2}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\}\frac{1}{T}\xi_r^*)\}^{-1}(\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\} - \frac{m_e c^2}{B_{eq}}\mu^*\frac{1}{q_e q^*}\frac{1}{cT}\xi_r^* + \frac{m^* c}{\Omega_e q^*}\frac{1}{(B_z^*)^3}(\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\})^2\frac{1}{T}\xi_r^*)\vec{e_\theta}$$

$$\vec{v} = -\{B_z^* + \frac{m^*}{\Omega_e q^*}(\frac{\vec{E_A^*}}{(B_z^*)^2}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\}\frac{1}{T}\xi_r^*)\}^{-1}(\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\} - \frac{\mu^*}{q^*\Omega_e}\frac{1}{T}\xi_r^* + \frac{m^* c}{\Omega_e q^*}\frac{1}{(B_z^*)^3}(\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\})^2\frac{1}{T}\xi_r^*)\vec{e_\theta}$$

$$\vec{v} = -\{B_z^* + \frac{m^*}{q^*}\frac{\xi_r^*}{T\Omega_e}(\frac{\vec{E_A^*}}{(B_z^*)^2}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\})\}^{-1}(\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\} - \frac{\mu^*}{q^*}\frac{\xi_r^*}{T\Omega_e} + \frac{m^* c}{q^*}\frac{1}{(B_z^*)^3}\frac{\xi_r^*}{T\Omega_e}(\vec{E_A^*}\sin\{m2\pi(t^* - \frac{R_0\theta}{\lambda}) + \frac{\pi}{2}\})^2)\vec{e_\theta}$$