Parameter standardization

Definition

c : lightspeed

$$m = m_e m^*$$

$$q=q_eq^*$$

$$v = cv^*$$

T ULF wave period

$$x = cTx^*$$

$$ec{B}=B_{eq}ec{B^*}$$

$$ec{E}=B_{ea}ec{E^*}$$

$$t = Tt^*$$

SO,

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

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

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

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

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

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

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

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

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

$$ec{v} = -\{B_z^* + rac{m^*}{\Omega_e q^*}(rac{ec{E_A^*}}{(B_z^*)^2}\sin\{m2\pi(t^* - rac{R_0 heta}{\lambda}) + rac{\pi}{2}\}rac{1}{T}\xi_r^*)\}^{-1}(ec{E_A^*}\sin\{m2\pi(t^* - rac{R_0 heta}{\lambda}) + rac{\pi}{2}\} - rac{m_e c^2}{B_{eq}}\mu^*rac{1}{q_e q^*}rac{1}{cT}\xi_r^* + rac{m^*c}{\Omega_e q^*}rac{1}{(B_z^*)^3}(ec{E_A^*}\sin\{m2\pi(t^* - rac{R_0 heta}{\lambda}) + rac{\pi}{2}\})^2rac{1}{T}\xi_r^*)ec{e}_{ heta}$$

$$ec{v} = -\{B_z^* + rac{m^*}{\Omega_e q^*} (rac{ec{E_A^*}}{(B_z^*)^2} \sin\{m2\pi(t^* - rac{R_0 heta}{\lambda}) + rac{\pi}{2}\} rac{1}{T} \xi_r^*)\}^{-1} (ec{E_A^*} \sin\{m2\pi(t^* - rac{R_0 heta}{\lambda}) + rac{\pi}{2}\} - rac{\mu^*}{q^*\Omega_e} rac{1}{T} \xi_r^* + rac{m^* c}{\Omega_e q^*} rac{1}{(B_z^*)^3} (ec{E_A^*} \sin\{m2\pi(t^* - rac{R_0 heta}{\lambda}) + rac{\pi}{2}\})^2 rac{1}{T} \xi_r^*) ec{e}_{ heta}$$

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