on Anomalous Cross Field Flux

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In order to investigate the effect of radial electric field on the anomalous cross field ion flux, the inhomogeneous radial electric field is introduced trough the invariance of guiding center particle orbit to the gyrokinetic solution in a toroidal system. As in the case of linear stability theory, the homogeneous radial electric field E_r , to the first order of E_r , just makes the Doppler shift, and no influence on the anomalous cross field flux. This elimination of E_r -effect has also been confirmed in the general expression of Shaing's[1].

In general, the cross field flux Γ has been expressed by a triple integral in velocity space, which may need laborious computer works to evaluate. In order to concentrate to the radial electric field effect, the integral has been simplified to a single integral with respect to the modified energy $\tilde{E}$ approximating the curvature drift frequency being proportional to $\tilde{E}$: $\omega_D = \omega_D \tilde{E}$.

By assuming that the power spectrum of $e\tilde{\phi}/T$ can be separated into the k (wave number)-space and ω (frequency) -space, the anomalous cross field flux has been expressed by the sum of gradients of density, temperature, magnetic filed and electric field like neoclassical form[1]:

$$\Gamma_{AN} = \sum_k \left|\frac{cT}{eB}k_\theta\right|^2 \left|\frac{e\phi}{T}\right|_k^2 N\left\{-I_0\frac{N'}{N} - \left(\frac{3}{2}I_0 - I_1\right)\frac{T'}{T} - 2I_1\frac{\langle B\rangle'}{\langle B\rangle} - \frac{\pi}{4}\frac{v_E}{v_i}I_{\frac{1}{2}}\frac{E_r'}{E_r}\right\}$$

where I_i is the moment integral with respect to frequency. The electric field term has been eliminated in the above expression. It is involved in the frequency moment integral as the Doppler shift. The third and fourth terms in the curly braces are the new terms.

Each term in the above anomalous flux Γ_{AN} can also be expressed by the sum of the discrete mode (certain instability or pole contribution) and the continuum contribution induced by the wave particle resonance condition. In the case of the ion temperature gradient mode, and the continuum contribution may become a principal term. We evaluated this continuum contribution due to the curvature drift resonance assuming a simple frequency power spectrum of scalar potential fluctuations, and obtained[1]:

$$\Gamma_{AN} = \sum_k \left|\frac{cT}{eB}k_\theta\right|^2 \left|\frac{e\phi}{T}\right|_k^2 \frac{N}{\omega_s}\left\{-\frac{N'}{N} - 3\frac{\langle B\rangle'}{\langle B\rangle} - \frac{\sqrt{\pi}}{2}\frac{v_E}{v_i}\frac{E_r'}{E_r}\right\}$$

The second term which expresses the effect of curvature of mean magnetic field lines, was not so important in the case of the CHS device[1].

Combining the anomalous flux Γ_{AN} with the neoclassical ion and electron fluxes, and introducing into the ambipoler condition, we have a first order differential equation with respect to the radial electric field:

$$-\frac{d_{AN}}{a_{NC}}\frac{dE_r}{dr} + E_r = E_{r0}$$

where the coefficients d_{AN} and a_{NC} are determined from the anomalous and neoclassical transport coefficients, respectively, and $E_{r0}(r)$ is the radial electric field without the shear flow(homogeneous electric field case)[1]. This means that the radial electric field is not just a parameter for the transport coefficients, but its radial profile should be determined consistently with plasma transport coefficients, i.e., the profile of E_r should be closely related to plasma transport coefficients.

The general solution of the above first order differential equation has been obtained, which also yields an approximate solution expanded in terms of the shear flow effect. For a case of experimental profiles of density and temperature in CHS, this approximate solution has been numerically evaluated. The result indicate that the radial profile of the electric field shows similar tendency as experimental one, and that the shear flow effect becomes much important in the plasma peripheral region[1].

[1]T.Yamagishi and H.Sanuki; Effect of Anomalous Plasma Transport on Radial Electric Field in Torsatron/Heliotron, NIFS-310 (1994).