§25. Collisionless Pitch Angle Scattering of Plasma Ions at the Edge Region of an FRC

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Motion of a plasma ion gyrating around the separatrix of a field-reversed configuration is studied. The action integral J defined by:

$$J \equiv \frac{1}{2\pi} \oint P_r \, dr$$

will be constant if an ion is traveling at a uniform magnetic field. While, it changes as the ion passes through the domain of an x-point. An example of the numerical calculation on the action integral for an ion (Fig.1) verifies the phenomena. An abrupt step-like change in the action integral, however, is observed when an ion goes through the domain of an x-point. This phenomena is understood as collisionless stochastic scattering of pitch angle.

In case of a particle with positive canonical angular momentum P_θ, resultant correlation coefficients of action integral between before and after the scattering appear to be stochastic in some cases. As an example, values of J before and after the scattering are illustrated in Fig.2. The scattering might be isotropic, since the distribution of the action integral J after the scattering tends to be the one expected analytically.

The differences of action integrals between before and after the scattering (ΔJ) for ions with the same pitch angle are observed. When ions have a comparatively large action integral J, the ensemble mean square $\langle(\Delta J/J)^2\rangle$ is small and the motion is adiabatic. If the ensemble square average is equal to $1/e^2$, then we will define the corresponding action integral as the adiabatic boundary. Adiabatic boundary is presented in Fig.3. One has to notify that extensive stochastic region is shown at small absolute value of P_θ, however, this region decreases as $|P_\theta|$ increases. It indicates that an ion exhibits a stochastic behavior when gyrating center is located in the vicinity of an x-point. On the other hand, an adiabatic behavior appears when gyrating center is located slightly away from an x-point.

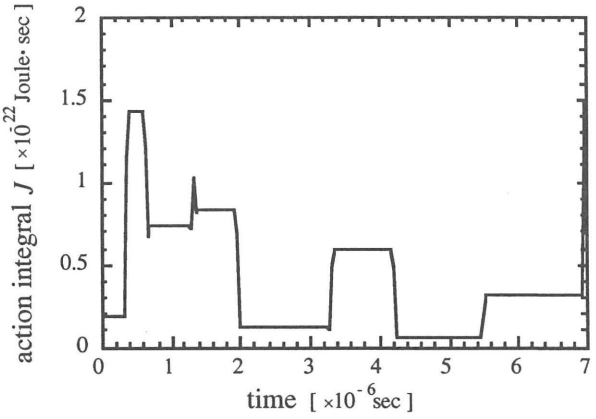

Fig. 1 An example of the numerical calculation on the action integral J to particle motion in the edge region of an FRC.

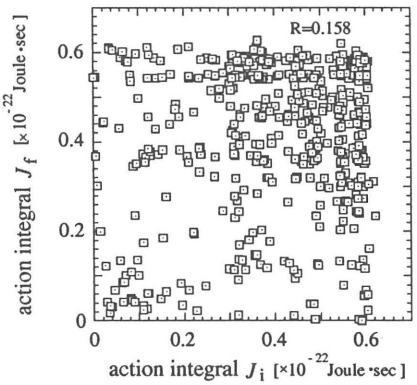

Fig. 2 Correlation diagram of the action integral between before (J_i) and after (J_f) passing the scattering region. The correlation coefficient R is also indicated in the diagram.

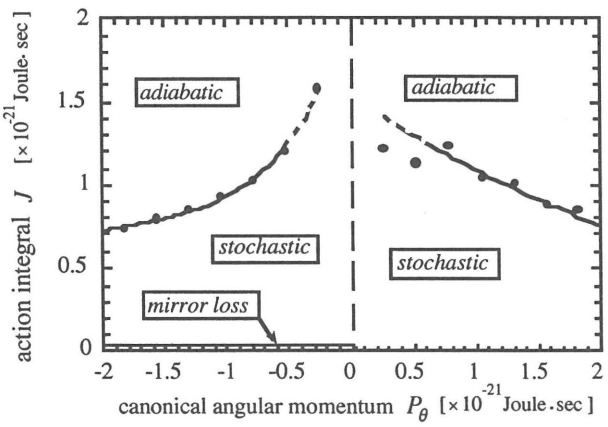

Fig. 3 Boundary values of the action integral J versus canonical angular momentum P_θ. A particle with larger J than the boundary value plays adiabatic behavior. The boundary of the mirror-loss is also indicated by solid line.