§10. Basic Study for Controlled Confinement of Particles with a Single Sign of Charge

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Magnetized non-neutral plasma that solely consists of electrons, a pure electron plasma, wears a peculiar property of conservation in total number of particles, energy and angular momentum in electro-magnetic traps with perfect axi-symmetry. In theory the most dominant factor comes from the contribution of electro-magnetic momentum originating from the vector product of the space-charge electric filed of the electrons and the external magnetic field. This contribution is expected to be larger than the kinetic momentum by a factor of the width of the density distribution divided by the average gyro-radius.

On the basis of drift-kinetic equation, a closed model is proposed within a framework of the quasi-linear theory that includes ExB drift and resonant wave-particle interaction along the magnetic field. [1] This model has successfully integrated several observational aspects of the radial transport of non-neutral plasma particles under azimuthally rotating electric fields. The essence of the model is summarized as follows:

(a) The driving electric field belongs to a body wave (Trivelpiece-Gould mode) that keeps a global structure in the transverse plane.
(b) The azimuthal wave field drives radial drift that results in a net flow of resonant particles.
(c) The same azimuthal electric field exerts a torque to the plasma as a dielectric medium producing an increment in the angular momentum that is originally negative to induce redistribution of the density profile (i.e. radial transport). This is associated by the increment of the potential energy of the particle system.
(d) The resonant radial transport is also associated by the axial acceleration (Landau damping).
(e) The power flowing from the body wave is fully converted into the potential energy and the kinetic energy with a local ratio of $\ell\omega_r/(\omega-\ell\omega_r)$, where ω_r is the local rotation frequency of the ExB drift by the self-field and ω is the frequency of the excited wave.

The essential points of the theoretical model are quantitatively examined with experiments [2] whose essence is summarized as follows:

(f) The rotating electric field is confirmed to propagate in the plasma as the TG mode.
(g) Utilizing that the electric field at the surface of the surrounding wall is measurable in terms of the current of the image charge, the radial distribution of the wave potential as eigenfunction is determined in absolute value.
(h) The rate of change in the observed density distribution is quantitatively consistent with the quasi-linear expression of the transport equation the theory predicts.
(i) The time evolution of the observed distribution of the electron temperature exhibits an inward shift of the high-temperature layer that is consistent with the theory. The absolute value of the temperature is also consistent with the rate of radial transport in both theory and experiments.
(j) The compression and expansion of the density profile occur depending on the sign of the azimuthal mode number ℓ of the TG wave.

Extremely slow transport in thermal equilibrium state is quantitatively analyzed on the basis of a newly proposed scheme of data analysis. The new results are summarized in ref.3.

References

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2) Y. Soga, Y. Kiwamoto and N. Hashizume, Phys. Plasmas No.13, No.5, 052105-1-7 (2006).
3) J. Aoki, Y. Kiwamoto and Y. Kawai, Phys. Plasmas Vol.13, No.11, 112109-1-8 (2006).