

§12. Super Ion Acoustic Double Layer

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Recently, we have investigated a self-organization process in a kinetic plasma. In order to clarify the mechanism of the spontaneous generation of a structure in an "open" system, ion-acoustic double layer is chosen as an illustration of this process.

Several fundamental processes for this research are revealed until last years. Especially, the key-point of the generating mechanism of the super ion-acoustic double layer is the nonlinear shifting from normal ion-acoustic instability to the electron-ion two-stream instability. In this year, by introducing the kinetic entropy, we have tried to explain the dynamical relationship between creation of a double layer, normal and super, and entropy production.

The total entropy of the system at time t , $S_j(t)$, is defined by

$$S_j(t) = - \int_{-\infty}^{\infty} dv \int_0^{L_X} dx f_j(x, v, t) \ln f_j(x, v, t),$$

where $f(x, v, t)$ is the velocity distribution function for the species of the plasma ($j = i(ion), e(lectron)$) and L_X represents the system length. Figure 1 shows the evolution of the system entropy as a function of time in the case of the constant current system. The duration of double layer is shown by the hatched area in this figure. It is evident that entropy is produced in accordance with creation of a double layer structure and the production is stopped when it decays.

In order to clarify the role of ions and electrons for the structure generation, we checked the entropy production rate, dS/dt , in the simple case (no external energy source). Figure 2 shows the entropy production rate as a function of time, solid line and dashed line are for ions and electrons, respectively. The peak time of ion's entropy production rate appears earlier than the electron's one and after decaying of ion's entropy production, electron's entropy production is stopped. This shows that the modification on the electron's phase space (acceleration and deceleration of electrons)

is led by the modification on the ion's phase space (generation and degeneration of V-shaped hole structure). The generation and degeneration process of the "normal" ion-acoustic double layer are governed by ions. In the cases of the constant voltage system and the constant current system, temporal evolutions are also similar.

It is to be noted that such an unexpected highly ordered structure is spontaneously created when a fresh free energy is externally supplied and a generated entropy is released to the outside, and also that an extremely large collisionless dissipation (anomalous resistivity) arises simultaneously, in more detail, the entropy production rate is maximized as an orderliness is created, while it is minimized as it decays.

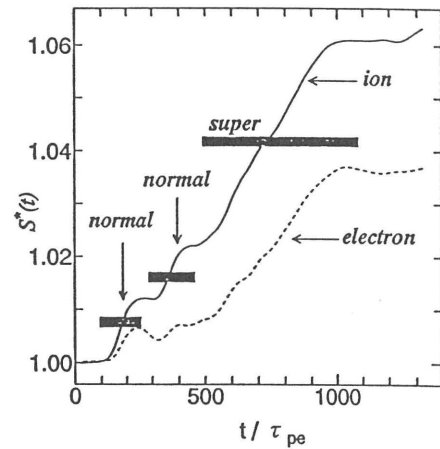


Figure 1

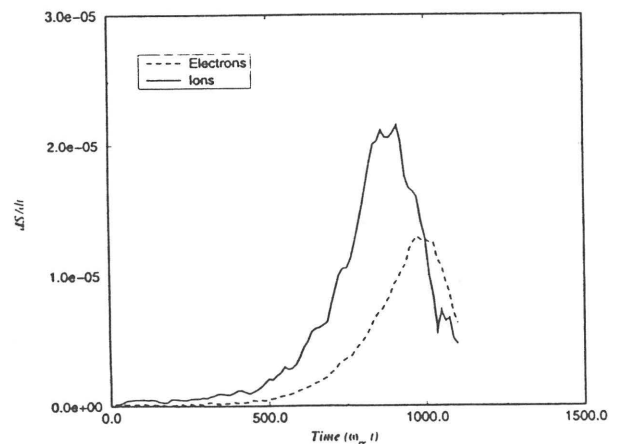


Figure 2