

§10. Kinetic Self-Organization — 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 (IADL) is chosen as an illustration of this process.

We would like to discuss the relationship between the formations of IADL and the kinetic entropy production rate. Before calculating the entropy production rate in terms of the quantities which characterizes the irreversible processes, we shall introduce the definition of the kinetic entropy as a function of time t , $S_j(t)$

$$S_j(t) = - \int_{-\infty}^{\infty} dv \int_0^L dx f_j(x, v, t) \ln f_j(x, v, t), \quad (1)$$

where $f(x, v, t)$ is the velocity distribution function, the suffix j stands for either electrons or ions and L denotes the system length.

Figure 1 shows the temporal evolution of the entropy production rate, $dS_j(t)/dt$, for the closed (top), the semi-open (middle), and the open (bottom) system, respectively. The solid line and dashed lines correspond to the entropy production rate for ions and electrons, respectively. The square mark indicates the potential gap of the generated DL, namely, the generation of the ordered structure. One can see that the entropy production rate is maximized when the IADL structure is formed, while the entropy production rate is minimized when the IADL structure is destroyed. Especially, in the open system, it should be noticed that the entropy production rate becomes negative, namely, the entropy inside the system is emitted towards the external system. The difference of the peak time between the electron's and ion's entropy production rate 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.

