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Coarse-grained entropy of collisionless plasemas

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It is known space plasmas often have non-equilibrium distribution functions because their binary collision frequencies are extremely low. Given a non-equilibrium distribution f(x,v), it is possible to calculate information theoretic entropy by integrating f log f. It is known, but not well understood, that the information theoretic entropy is not directly related to thermodynamical entropy; thermodynamical entropy is defined only when the system is in equilibrium.

The author has reported difficulties related to collisionless entropy at the last fall meeting of SGEPSS, and proposed a way to calculate the upper limit of free energy via virtual adiabatic processes. In the present paper, the problem of coarse-graining, which may be the most serious difficulty in application, will be discussed

It can be easily shown that the entropy calculated from the distribution function in the Vlasov equation is a time constant. Therefore, this entropy cannot be regarded as to represent the irreversibility of collisionless systems. When we introduce so called coarse-grained distribution function, which is the one averaged over small but finite volumes in the phase space, the entropy can change in the time evolution. Although it is yet to be proved that this entropy is a time-increasing function, we can relate this entropy to thermodynamical quantities by assuming that.

There is, however, a problem in coarse-graining; the value of entropy depends on the coarse-graining size. This may be a serious problem in application. The distribution functions obtained by spacecrafts are coarse-grained by the resolution of the detectors, and thus the calculated entropy must depend on detectors. Kinetic simulation has the same problem; the entropy must depend of the grid size. The details of this problem and possible solutions will be discussed in the presentation.

Keywords: Collisionless Plasma, Vlasov Equation, Entropy, Thermodynamics