Phase space filamentation and departure from thermodynamical equilibrium in low collision fluids

D. Del Sarto[1], F. Bertrand[1], A. Ghizzo[1] and F. Pegoraro[2]

[1] Institut Jean Lamour CNRS 7198, Université de Lorraine, 54000 Nancy, France

[2] Dipartimento di Fisica "Enrico Fermi", Università di Pisa, 56100 Pisa, Italia

contact: daniele.del-sarto ⊕ univ-lorraine.fr

In a fluid medium, the probability to find a particle with a velocity $\boldsymbol{v}$ in a position $\boldsymbol{x}$ at a time t is given by the distribution function $f(\boldsymbol{x}, \boldsymbol{v}, t)$ of the particle species in the phase-space. Its evolution is ruled by transport equations of Boltzmann type, very similar for both neutral gases and ideal plasmas, i.e., globally neutral "gases" constituted by free electrons and ions. A common feature of all these transport equations is the natural tendency to generate phase-space filaments, i.e., to make the distribution function evolve so to fill regions of the $(\boldsymbol{x}, \boldsymbol{v})$-space, which get increasingly narrower in time. This "*phase-space filamentation*", is opposed by collisions or dissipation effects and can be important in low collision fluids. An example is shown in Fig. 1.

Here we discuss some features of this mechanism and its implications for the evolution of macroscopic quantities, like pressure, by focussing on the way it can induce a significant departure from thermodynamical equilibrium conditions. The physics of low collision plasmas, ubiquitous in astrophysics and thermonuclear fusion experiments, provides a framework from which to tap examples of practical interest, a few of which we will discuss (see, e.g., Refs. [3, 4]).

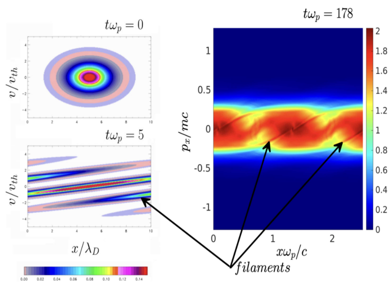

Figure 1: Left: example of "kinematic" phase-space filamentation of an initial Gaussian distribution of free streaming particles. Right: formation of filaments in an "enhanced filamentation" process, associated to an instability met in low collision plasmas. The figure is taken from [1, 2].

References

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