Linear Landau damping and instabilities in fluid-particles interaction

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Under appropriate assumptions, a collisionless electrostatic plasma is well-described by the Vlasov-Poisson system. It is known since the seminal work of Landau that such plasma can exhibit a damping of the electric field for large times.
We present new results of linear damping properties for solution of a fluid particles model,

$$\begin{cases} \partial_t f + \boldsymbol{v} \cdot \nabla_x f - \nabla_x p(\varrho) \cdot \nabla_v f + D_\star \nabla_v \cdot ((\boldsymbol{u} - \boldsymbol{v}) f) = 0 \\ \partial_t(\alpha\varrho) + \nabla_x \cdot (\alpha\varrho\boldsymbol{u}) = 0 \\ \partial_t(\alpha\varrho\boldsymbol{u}) + \nabla_x \cdot (\alpha\varrho\boldsymbol{u} \otimes \boldsymbol{u}) + \alpha\nabla_x p(\varrho) = D_\star \int_{\mathbf{R}^3} (\boldsymbol{v} - \boldsymbol{u}) f \mathrm{d}v. \end{cases} \tag{1}$$

We linearize the system around solutions which are space homogenous and of maxwellian type for the particles, and we write the dispersion relation of the system in a similar manner to what is standard for the Vlasov-Poisson system. The main result [1] is that the acoustic energy is damped as $O(e^{-\lambda t}\cos(\omega t))$ with $\lambda > 0$, where $z = \omega - i\lambda$ is the root with the smallest imaginary part of the new dispersion relation. This dispersion relation is also used to characterize the particles profiles which are linearly unstables
To validate the theory, we assembled a numerical method based on a third order semi-lagrangian scheme for the Vlasov part coupled with a standard finite volume scheme for the gas part. The numerical results show that the damping and instabilities effects predicted by the linearized equations is observed both in the linear and the nonlinear simulations.

Références

[1] C. Buet, B. Després, V. Fournet. *Analog of Linear Landau Damping in a coupled Vlasov-Euler system for thick sprays*, 2023. Https ://hal.science/hal-04265990, hal-04265990. Submitted.

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