Research Highlight: Numerical simulation of Landau damping

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Landau damping is an interesting phenomenon is plasma physics. In a system with existence of both kinetic energy and electrical energy, without any external force, the electrical energy may decay to zero as the system evolves, which is counter-intuitive when comparing this to the pendulum, where the kinetic energy and the gravitational potential energy never decay if there is no damping. Landau damping can be understood by numerically solving the Vlasov equation. However, due to the finite degrees of freedom in the simulation, an artificial numerical effect called "recurrence" may appear, which means that when the "recurrence time" is reached, the electrical energy predicted by the numerical simulation hops back to a large value. Such a phenomenon requires us to use a large number of degrees of freedom in the simulation to ensure the reliability of the numerical solution.

Dr Cai and his collaborator find that when the Vlasov equation is solved by the Hermite spectral method, application of a simple spectral filter can effectively relax the recurrence problem. In [CW18], it is analyzed how and why the recurrence is suppressed by the spectral filter. In general, when no filter is applied, due to the aliasing effect, high-frequency modes in the solution may be added to the modes with lowest frequency, causing incorrect prediction of the plasma density. By applying the filter, such high-frequency modes are removed at a desired rate, making the simulation much more robust. It is also formally shown that applying the filter will not affect the decay rate.

Reference:

[CW18] Z. Cai and Y. Wang, "Suppression of Recurrence in the Hermite-Spectral Method for Transport Equations". SIAM Journal on Numerical Analysis, 56, no. 5 (2018): 3144-3168.