

## Master project offer: Symplectic flow maps in plasma physics

In this internship, you will [simulate ion-electron interactions](#) using Vlasov-Poisson equations:

$$\begin{aligned} \partial_t f^e + v \partial_x f^e + \frac{q^e}{m^e} E \partial_v f^e &= 0 \\ \partial_t f^i + v \partial_x f^i + \frac{q^i}{m^i} E \partial_v f^i &= 0, \end{aligned} \quad (1)$$

where the ion and electron distribution functions  $f^i, f^e$  are connected via the electric field:

$$\partial_x E = \rho^e + \rho^i \quad \rho^{e/i} = \int f^{e/i} dv. \quad (2)$$

To simulate this we use a so-called characteristic mapping method [1] that is a [semi-Lagrangian method](#) that evolves an underlying grid (shown in fig. 1a) in time. This newly developed method allows studying fine-scale structures of turbulence shown in fig. 1b. However, so far it only addresses single electron dynamics. The task is to extend [1] to solve eqs. (1) and (2) coupling electrons with ions.

Proposal-link

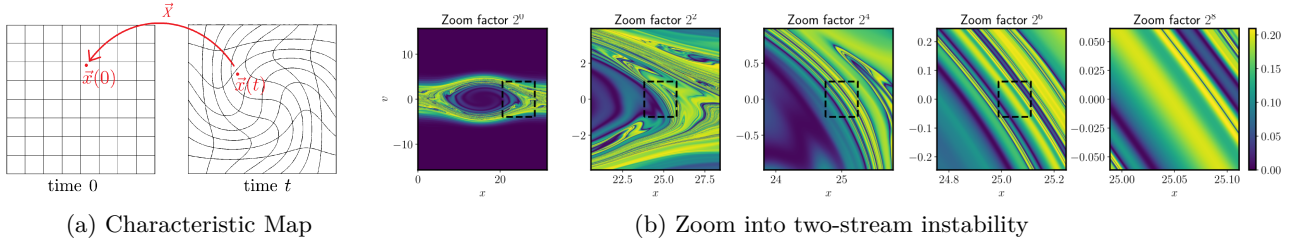
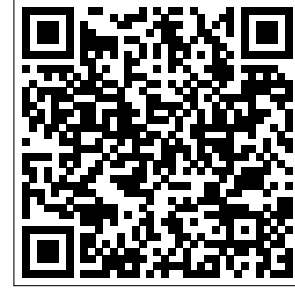


Figure 1: Visualizing the idea of CMM for the two-stream instability in plasma.

**Who?** This internship targets [physicists in their master's](#) with an understanding of numerical mathematics and who are comfortable with [programming in Python/Matlab or C++](#).

### Workplan:

The tasks for this project can be divided into the following points:

- Implementation of numerical flow iteration [2] for eqs. (1) and (2).
- Combination with existing framework [1].
- Simulation of non-linear Landau damping and validation.

### Contact Persons:

Philipp Krah: [philipp.krah@univ-amu.fr](mailto:philipp.krah@univ-amu.fr)  
Zetao Lin: [zetao.lin@etu.univ-amu.fr](mailto:zetao.lin@etu.univ-amu.fr)  
Kai Schneider: [kai.schneider@univ-amu.fr](mailto:kai.schneider@univ-amu.fr)

## References

- [1] Philipp Krah, Xi-Yuan Yin, Julius Bergmann, Jean-Christophe Nave, and Kai Schneider. A characteristic mapping method for vlasov–poisson with extreme resolution properties. *Communications in Computational Physics*, 35(4):905–937, June 2024.
- [2] Rostislav-Paul Wilhelm, Jan Eifert, and Manuel Torrilhon. High fidelity simulations of the multi-species vlasov equation in the electro-static, collisional-less limit. *arXiv preprint arXiv:2404.18549*, 2024.