Inverse landau damping using VP

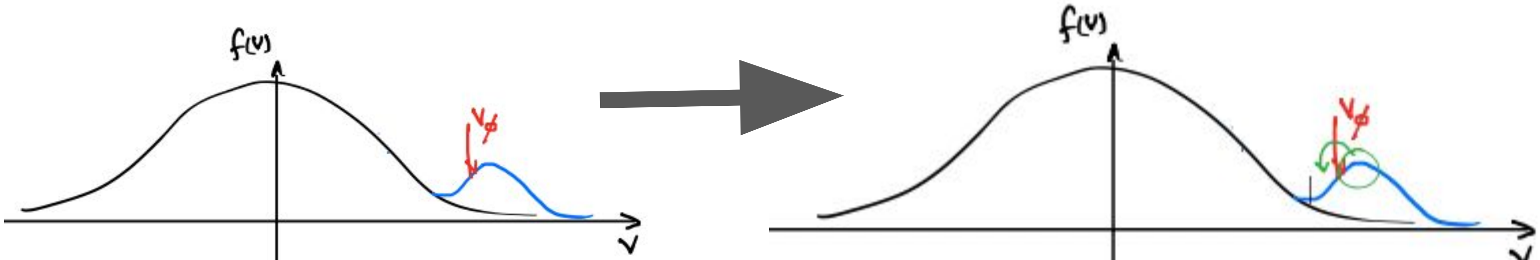
PHYS 783 - Hasith Perera

Introduction

- I wanted to look for inverse Landau damping for a change !
- Just to recall from class the condition for inverse landau damping if as follows

$$\omega_i = \frac{\pi}{2}\omega_{pe}\frac{4\pi e^2}{k^2 m_e}\left.\frac{dF_{e0}}{dv_z}\right|_{v_z=\omega_r/k}$$

- Need the following
    - Wave with known speed
    - Put a bump on the tail **positive velocity gradient** in the phase space density around the resonant frequency v_phi



VP - Summary

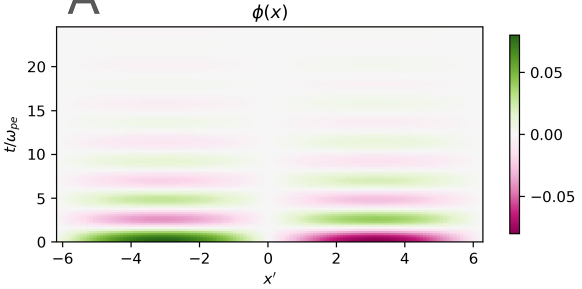
- This is a 1D-1V Vlasov- Poisson solver
- The electric potential $\phi(x)$ is solved using a **Green’s function** method.
- Multiple species are supported.*
- Krook collision operator is available. (I didn’t test or use it in this project)
- Phase space densities are evolved using a 3rd order **Adams-Bashforth method**

- All Simulation run times for the simulation shown here are < 2 mins on a single core. (No parallelization is used)

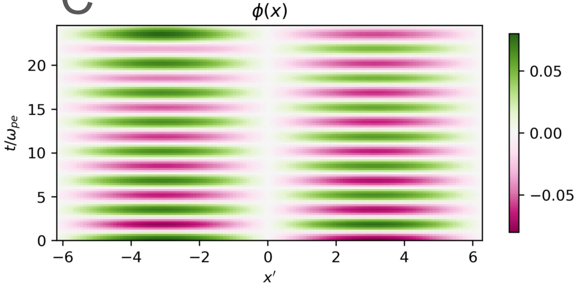
Standing wave - attempt 1

- Initial tests were done to make sure I can see landau damping using a **standing wave initialization**
- A bump on the tail was initialized at ± 3.5 v_th close to the resonance
  - I see a slower decay when the bumps are added(dashed line) . But not a growth in the field

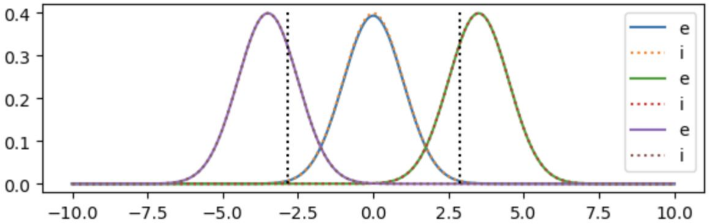
A



C

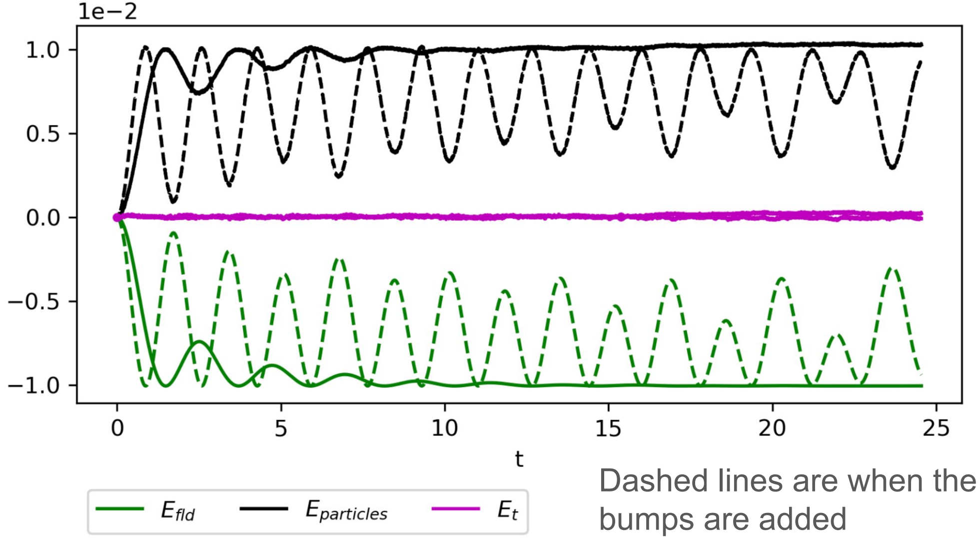


B



A cut at t = 0,
v_phi = 2.86, u = +/- 3.5

D

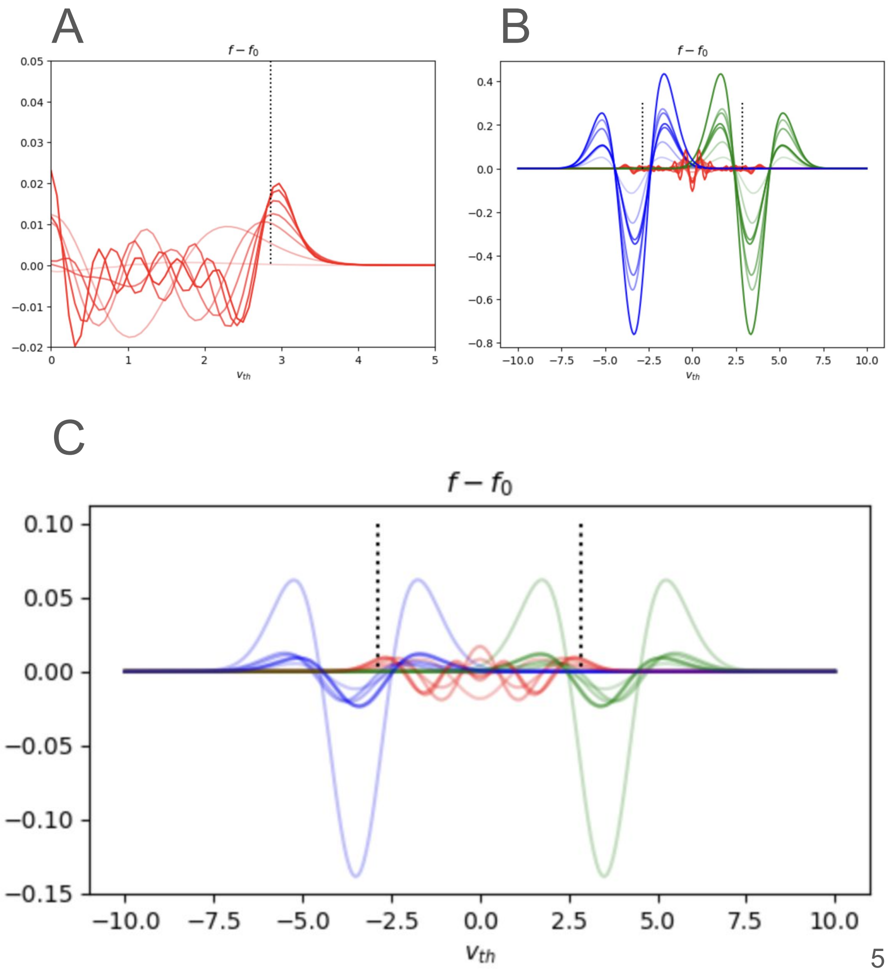


Dashed lines are when the bumps are added

Standing wave(contd)

- Let look for the signature in the integrated phase space density.
    - Plot A: landau damping simulation
    - Plot B: Blue and Green shows how the bumps on the tail evolves
        - I don’t fully understand what's going on there
        - It could be the amplitude is too large and the system is showing non-linear effects
    - Plot C: Tried a low amplitude run

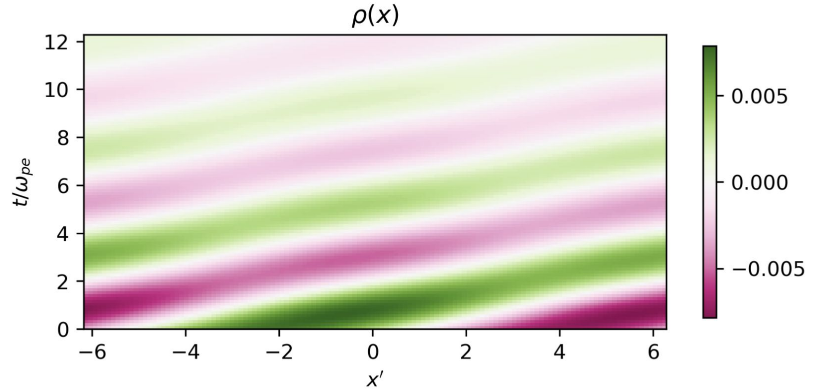
    There is a lot going on need to simplify the simulation even more

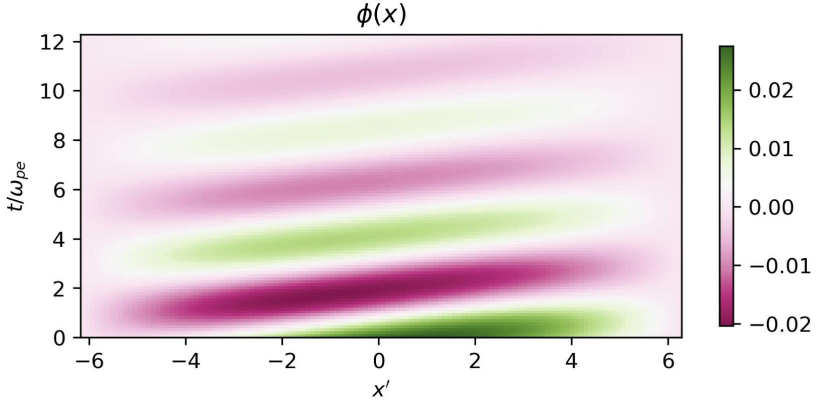


Single propagating wave - attempt 2

- This Initialization uses linear theory (we studied this exactly in Chap 8) to calculate the perturbation to the distribution function to get a travelling wave

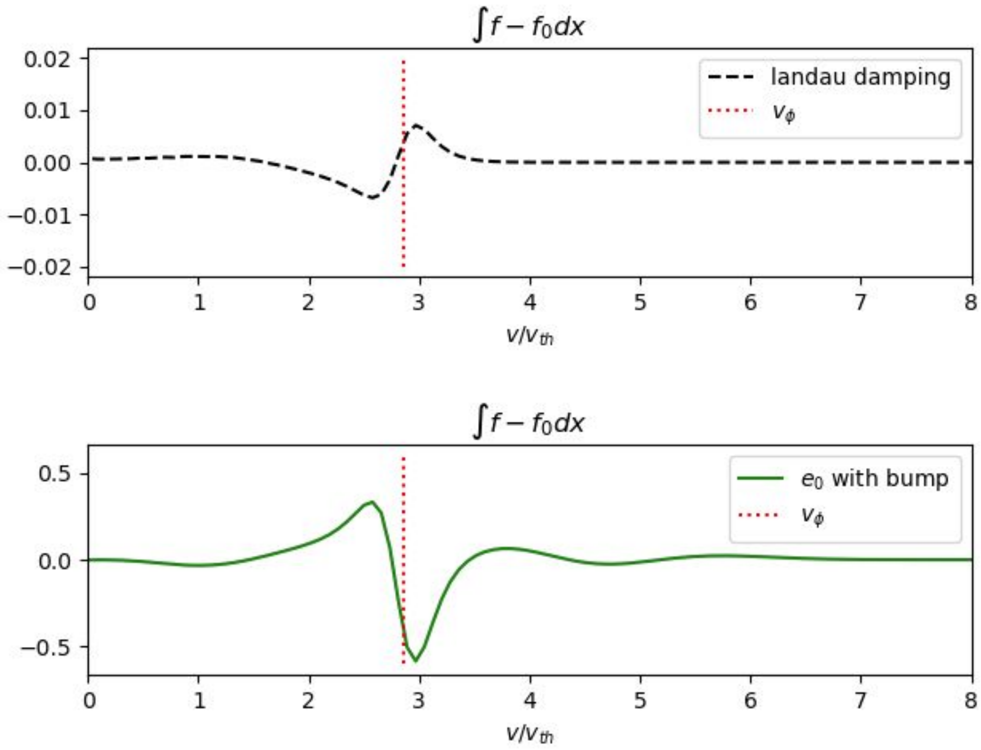
- Initial data looks usable
- **There were some issues** on the potential calculation (could be user error too)





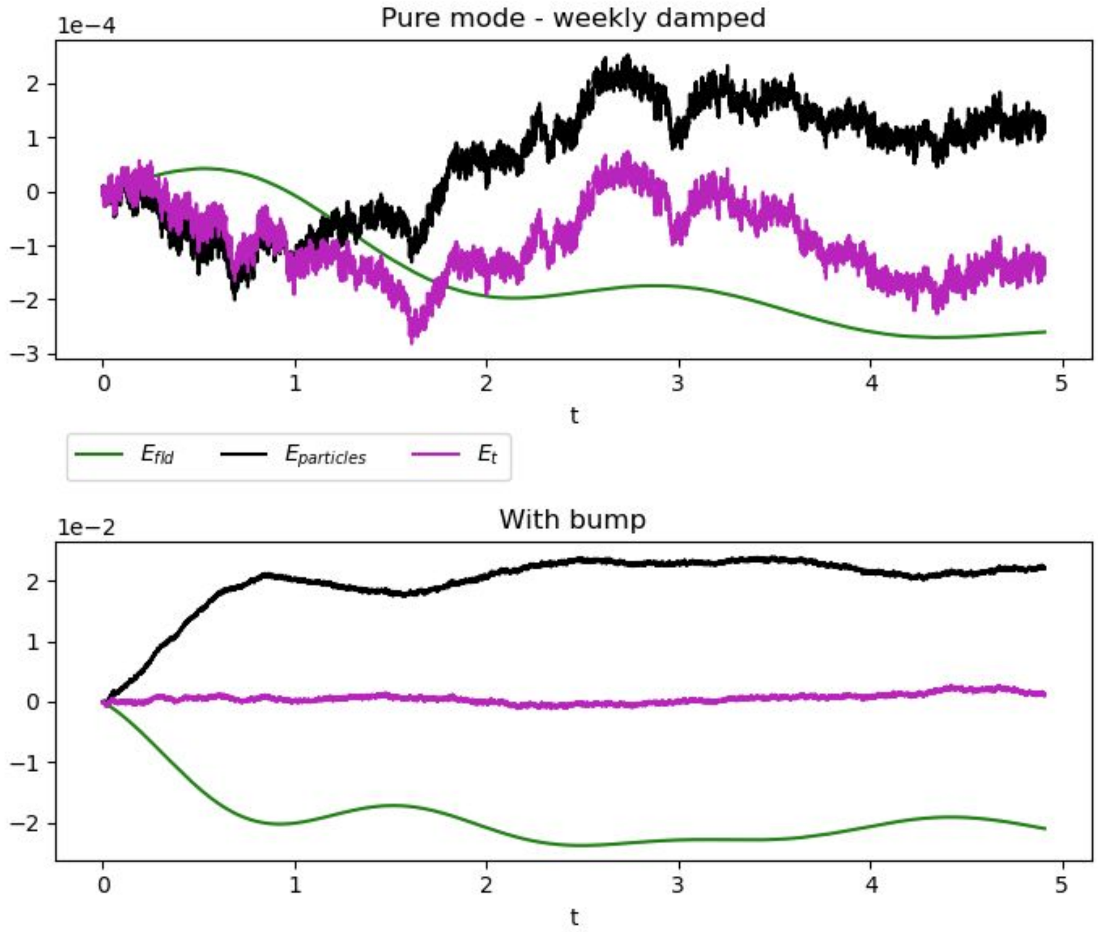
Single propagating wave - attempt 3

- 2 species (e and ions) + a bump on the tail externally added at u=3.5 v_th, t = 0
- Good news
    - At large time the change in phase space density shows **higher energy particles being moved to low energy**



Energy transfer

- Top plot:Weak Landau damping
- Bottom: With the added bump on the tail



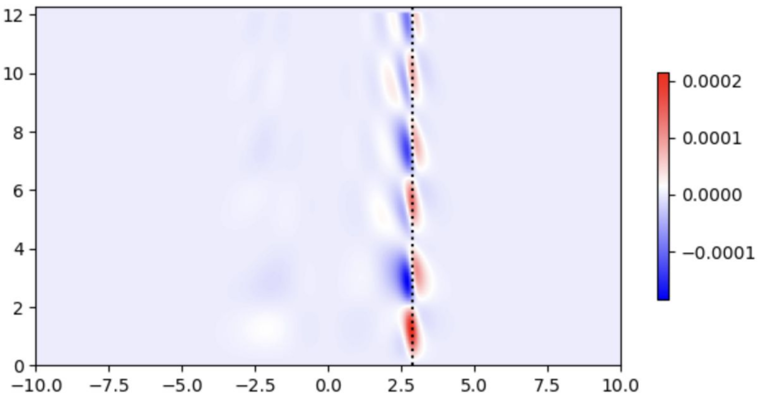
Field Particle Correlation

- FPC term plotted here

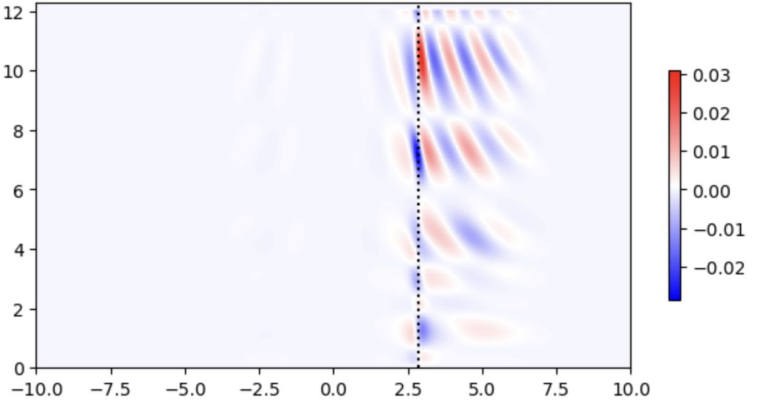
$$\frac{q_s v^2}{2}\frac{\partial \delta f_s(x,v,t)}{\partial v}E(x,t)$$

- Plot A: FPC for landau damping only
- Plot B: FPC for bump on the tail
- When the bump was added notice the signature close to the resonant velocity switched directions.
- But also at later in time we can find some particles that gained energy, This would explain why the field lost energy

A



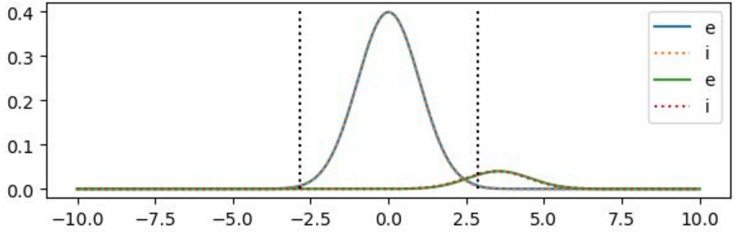
B

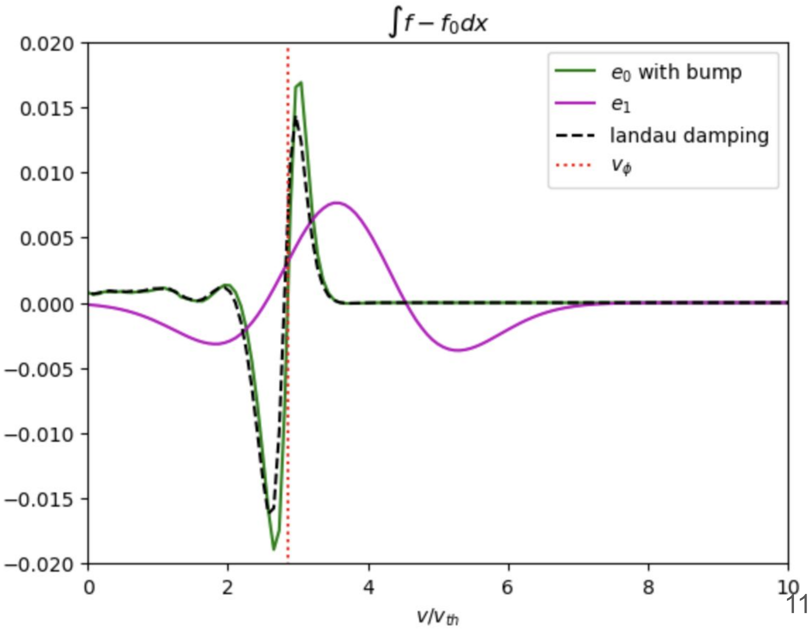


Thanks !

Single propagating wave - attempt 2

-
- Initialize a bump (with 2 new species)
    - Plot compares a pure landau damped simulation vs a simulation with a bump implemented via simulating 4 species





Species with the same charge and mass are not fully talking to each other !