1D gyrokinetic plasma (in units of $e\phi/T_e$ Ω_i^{-1} ρ_s)

$$\frac{dF_\alpha}{dt} \equiv \frac{\partial F_\alpha}{\partial t} + v_\parallel \frac{\partial F_\alpha}{\partial x_\parallel} - s_\alpha \frac{\partial \phi}{\partial x_\parallel}\frac{\partial F_\alpha}{\partial v_\parallel} = 0$$

$$s_e = -m_i/m_e \qquad\qquad s_i = 1$$

$$\frac{\partial^2 \phi}{\partial x_\perp^2} = -\int (F_i - F_e) dv_\parallel$$

$$F_\alpha = F_{0\alpha} + \delta f_\alpha$$

$$F_{0\alpha} = \frac{1}{\sqrt{2\pi} v_{\alpha t}} e^{-v_\parallel^2/2v_{\alpha t}^2}$$

$$\delta f \propto e^{ik_\parallel x_\parallel - i\omega t} \qquad\qquad k_\parallel v_\parallel/\omega \ll 1$$

$$\omega^2 = \omega_H^2 \equiv \theta^2 (m_i/m_e)\Omega_i^2$$

Let $\qquad y = \theta x_\parallel \qquad\qquad y = x_\perp$

$$\boxed{\frac{dF_\alpha}{dt} \equiv \frac{\partial F_\alpha}{\partial t} + v_\parallel \theta \frac{\partial F_\alpha}{\partial y} - s_\alpha \theta \frac{\partial \phi}{\partial y}\frac{\partial F_\alpha}{\partial v_\parallel} = 0}$$

$$\boxed{\frac{\partial^2 \phi}{\partial y^2} = -\int (F_i - F_e) dv_\parallel}$$

From WWLEE_course/Course@Columbia/1D_code.key

1D unmagnetized plasma (in units of $e\phi/T_e$ ω_{pe}^{-1} λ_{De})

$$\frac{dF_\alpha}{dt} \equiv \frac{\partial F_\alpha}{\partial t} + v\frac{\partial F_\alpha}{\partial x} - s_\alpha \frac{\partial \phi}{\partial x}\frac{\partial F_\alpha}{\partial v} = 0$$

$$s_e = -1$$

$$s_i = m_e/m_i$$

$$\frac{\partial^2 \phi}{\partial x^2} = -\int (F_i - F_e) dv$$

$$F_\alpha = F_{0\alpha} + \delta f_\alpha$$

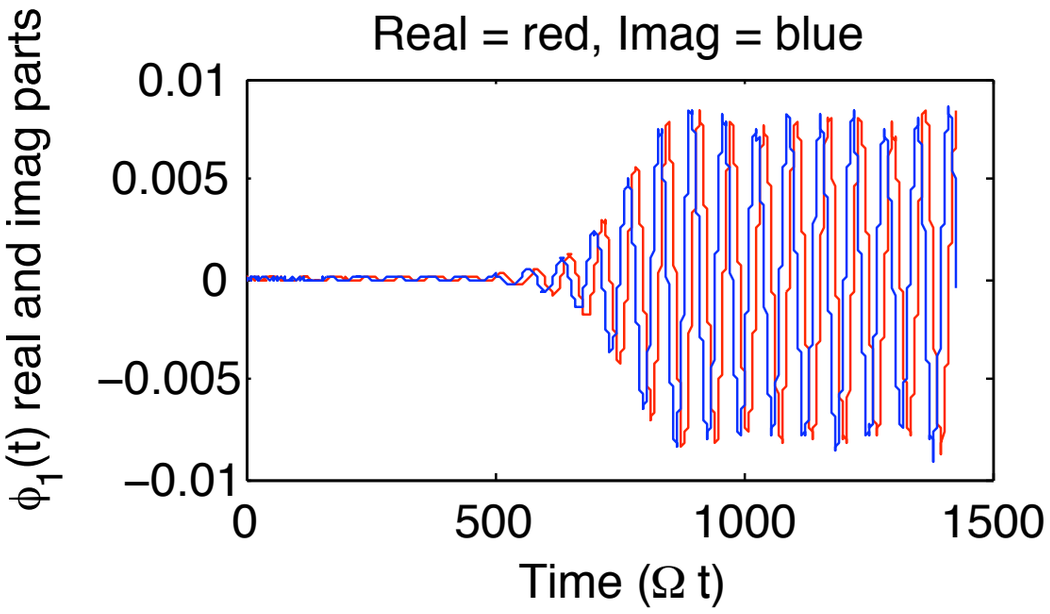
$$F_{0\alpha} = \frac{1}{\sqrt{2\pi} v_{\alpha t}} e^{-v^2/2v_{\alpha t}^2}$$

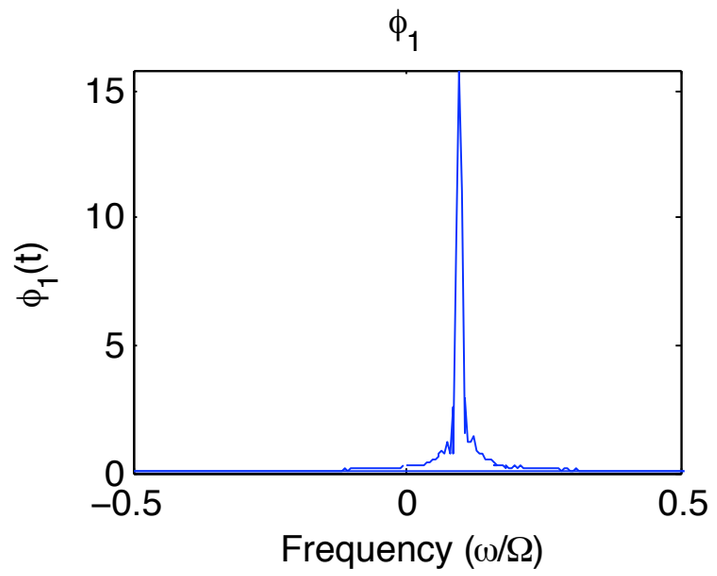
$$\delta f \propto e^{ikx - i\omega t}$$

$$kv/\omega \ll 1$$

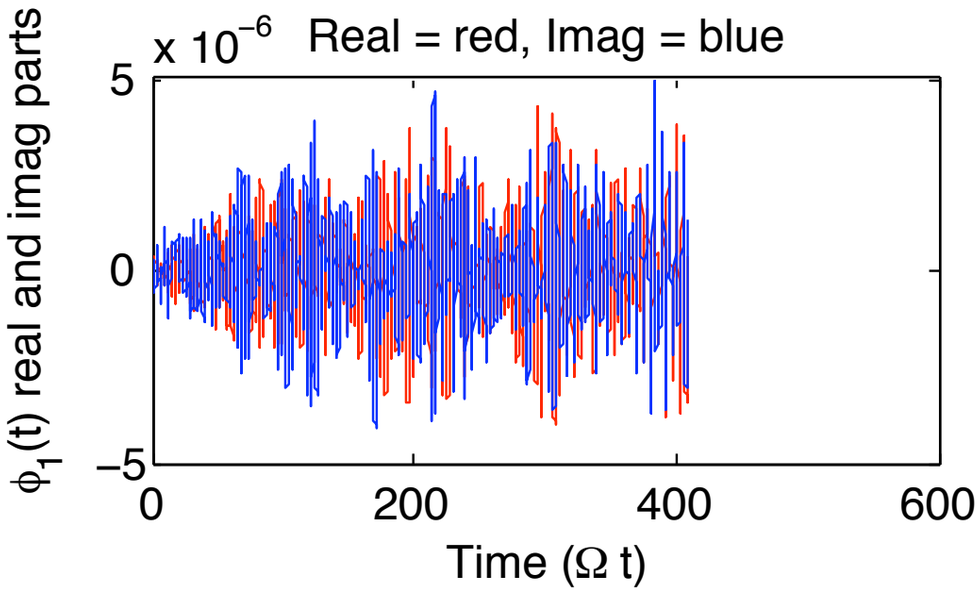
$$\omega^2 = \omega_{pe}^2$$

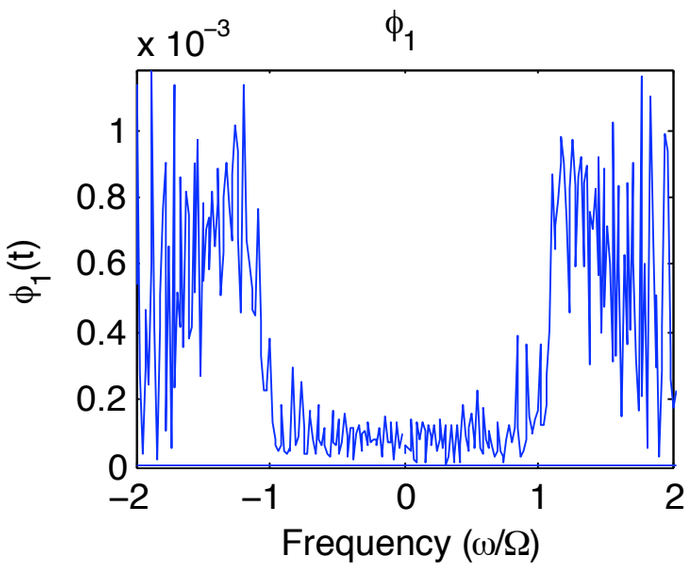
From WWLEE_course/Course@Columbia/1D_code.key






```
1. delta-f DW
Based on the CU version of the
code for delta-f. Recovered
the results from
Fig. 1 of the CPC paper.
tau=1;
vte=sqrt(1837);
vti=1/sqrt(tau);
theta=.01;
kappan=0.2
Ly=8;
Ny=16;
dt=1;
filter=1;
%nsteps=1024;
N=1000
dt=0.35
nsteps=4096
```






```
6. delt-f plasma waves
tau=1;
vte=1;
vti=sqrt(1/1837);
theta=1.;
kappan=0.0;
N=1,000;
nsteps=4096;
dt=0.1;
filter=1;

Theory: \phi =  10{-4} /sqrt{1000}
= 3x10^{-6}

Theory: freq= sqrt(1 + 3*0.75^2) =
1.64
```

-- Needs quiet start to see Landau damping.

From Document/MATLAB/Plots_CU/