Landau Waves: An Experimental Fact
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First experimental verification of Landau damping and Bohm-Gross dispersion in $\sim$ uniform 1-D plasma.

Wave launched at a steady (real) frequency $\omega$, controlled by an RF generator.

Detected at a variable distance.

FIG. 1. Diagram of the sodium plasma tube showing the probe arrangement.

Grids used so that the problem is approximately 1-dimensional.
Observed signal

Shows an oscillation strongly damped in space.

\[ \text{RECEIVED VOLTAGE} \]

\[ \text{PROBE SEPARATION (mm)} \]

FIG. 2. Interferometer output at 95 Mc/sec as a function of grid separation.

This is interpreted as giving the real and imaginary parts \( k = k_r + ik_i \).
Dispersion Relation

Shows agreement with full kinetic theory calculation for 

\[ \omega_p < \omega \lesssim 4\omega_p \]

[Bohm-Gross relation a poor approx for higher \( \omega \).]
Dispersion of Electron Plasma Waves
J.H. Malmberg and C.B. Wharton

Performed in a longer plasma column.
The transverse gradients are large.

![Graph](image)

**FIG. 1.** Electron density as a function of radial position.

Not quite as ideal a situation, but rather quieter signals. Basically similar technique.
Data Obtained

FIG. 2. Raw data. Upper curve is the logarithm of received power. Lower curve is interferometer output. Abscissa is probe separation.

Longer wave train allows more accurate k-determination.
Dispersion Relation

Has to account for transverse variation. Consequently is not simply
\[ \omega^2 \approx \omega_p^2[1 + 3(k\lambda_D)^2] \]

Theory and experiment agree well using exptl \( T_e \) (\( n_e \) adjusted within exptl uncertainty to fit). Agreement becomes exact if \( T_e \) is increased 10%.
Damping Agrees with Landau Theory

Plotting \((\log)k_i/k_r\) versus \((\omega/k_rv_{te})^2 = (v_p/v_{te})^2\) gives a straight line.

FIG. 4. \(k_i/k_r\) vs \((v_p/v)^2\). Solid curve is the theory by Landau.

Theory is verified over a factor of about 10 in damping decrement.
Ion Acoustic Waves

A.Y. Wong, N. D’Angelo, and R.W. Motley

Phys. Rev. Lett. 9 (1962) 415

In the plasma column of a Q-machine

![Graph showing phase velocity vs frequency for cesium and potassium.]

FIG. 1. Phase velocity of ion waves vs frequency, for cesium and potassium.

Have constant phase-velocity, independent of frequency.
Plasma temperature not well measured.
Density varied nearly a factor of 10.
Damping Decrement

Damping goes like $\exp\left(-\frac{x}{\delta}\right)$

- $\frac{1}{\delta} \propto \omega$. $\delta \approx 0.6\lambda$
- $\delta$ independent of $n$ (not collisions).
- $\delta \propto m_i^{-1/2}$

Consistent with Landau damping.