Magnetosonic shock waves in degenerate electron-positron-ion plasma with distinct spin densities

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This study investigates the dynamics of magnetosonic shock waves in a spin-polarized three-component quantum plasma, incorporating the effects of spin magnetization current and spin pressure within the quantum magnetohydrodynamic framework. Such plasmas, relevant to compact astrophysical environments (e.g., white dwarfs, magnetars) and high-energy-density laboratory experiments, exhibit unique dispersion and nonlinear features due to the interplay of quantum diffraction, positron imbalance, and spin polarization. We first derive and analyze the linear dispersion relation, systematically varying parameters such as plasma beta, magnetic diffusivity, positron concentration asymmetry, and spin polarization ratio. Numerical results (Fig. 1) reveal distinct sensitivities of the real and imaginary parts of the wave frequency, with magnetic diffusivity exerting a dominant influence on damping rates while quantum and spin effects strongly modify phase speeds. The phase velocity trends (Fig. 2) indicate that spin polarization can significantly modulate wave propagation, suggesting that magnetization control could be used to tailor wave transport in both astrophysical and experimental plasma regimes. Nonlinear analysis, carried out via the Korteweg–de Vries–Burgers equation, uncovers a transition between monotonic and oscillatory shock profiles depending on dimensionless plasma parameters (Fig. 3). This transition reflects the balance between dispersive, dissipative, and nonlinear effects, and provides insight into energy transport mechanisms in quantum magnetized plasmas. The combination of these linear and nonlinear results, supported by the detailed plots, offers a predictive understanding of how spin-resolved populations and positron imbalance shape magnetosonic shock behavior, opening pathways for targeted experimental verification in laser–plasma and astrophysical contexts.

Figure 1: Linear dispersion relation (real and imaginary parts)
It shows how the angular frequency varies with wavenumber for different plasma parameters. The real part reveals how phase speed is altered by spin polarization and positron imbalance, while the imaginary part highlights damping trends dominated by magnetic diffusivity.

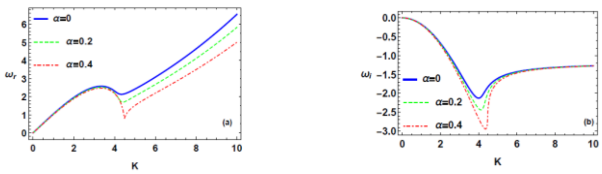

Figure 1: Real and imaginary part of the Dispersion

Figure 2 — Phase velocity vs. spin polarization
It demonstrates that increasing spin polarization can either accelerate or decelerate magnetosonic waves, depending on other plasma conditions. This tunability is particularly relevant for controlling wave transport in laboratory experiments.

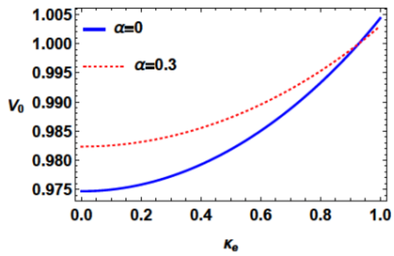

Figure 2: Phase velocity against spin polarization index

Figure 3 — Nonlinear shock profiles
Displays representative monotonic and oscillatory waveforms obtained from the KdV–Burger's equation for selected parameter sets. The switch between these profiles illustrates how dispersion–dissipation competition governs shock morphology and energy transport efficiency.

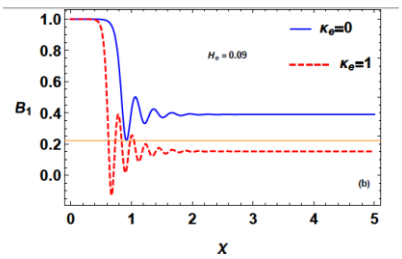

Figure 3: Oscillatory and monotonic shock profile

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