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Weakly Collisional Landau Damping and 3D BGK Modes: New Results on Old Problems[1]

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Landau damping and Bernstein-Greene-Kruskal (BGK) modes are among the most fundamental concepts in plasma physics. While the former describes unexpected damping of linear plasma waves in a collisionless plasma, the latter describes exact undamped nonlinear solutions of the Vlasov equation. There does exist a relationship between the two: Landau damping can be described as the phase-mixing of undamped eigenmodes, the Case-Van Kampen modes, which can be viewed as BGK modes in the linear limit. While these concepts have been around for a long time, unexpected new results are still being discovered. For Landau damping, we show that the textbook picture of phase-mixing is altered profoundly in the presence of collision. In particular, the continuous spectrum of Case-Van Kampen modes is eliminated and replaced by a discrete spectrum, even in the limit of zero collision. Furthermore, we show that these discrete eigenmodes form a complete set of solutions. Landau-damped solutions are then recovered as true eigenmodes (which they are not in the collisionless theory). For BGK modes, our interest is motivated by recent discoveries of electrostatic solitary waves in magnetospheric plasmas. While 1D BGK theory is quite mature, there appear to be no exact 3D solutions in the literature (except for the limiting case when the magnetic field is of infinite strength). For unmagnetized plasmas, we show that 3D solutions that depend only on energy do not exist. However, we are able to construct exact 3D solutions that depend on energy and angular momentum. We will compare theory with laboratory and space observations.

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