

DPP09-2009-000141

Abstract for an Invited Paper
for the DPP09 Meeting of
the American Physical Society

Kinetic Theory of Instability-Enhanced Collisional Effects¹

SCOTT D. BAALRUD, Department of Engineering Physics, University of Wisconsin-Madison

A generalization of the Lenard-Balescu collision operator is derived which accounts for the scattering of particles by instability amplified fluctuations that originate from the thermal motion of discrete particles (in contrast to evoking a fluctuation level externally, as is done in quasilinear kinetic theory) [1]. Emphasis is placed on plasmas with convective instabilities. It is shown that an instability-enhanced collective response results which can be the primary mechanism for scattering particles, being orders of magnitude more frequent than conventional Coulomb collisions, even though the fluctuations are in a linear growth phase. The resulting collision operator is shown to obey conservation laws (energy, momentum, and density), Galilean invariance, and the Boltzmann \mathcal{H} -theorem. It has the property that Maxwellian is the unique equilibrium distribution function; again in contrast to weak turbulence or quasilinear theories. Instability-enhanced collisional effects can dominate particle scattering and cause strong frictional forces. For example, this theory has been applied to two outstanding problems: Langmuir's paradox [2] and determining Bohm's criterion for plasmas with multiple ion species [3]. Langmuir's paradox is a measurement of anomalous electron scattering rapidly establishing a Maxwellian distribution in gas discharges with low temperature and pressure. This may be explained by instability-enhanced scattering in the plasma-boundary transition region (presheath) where convective ion-acoustic instabilities are excited. Bohm's criterion for multiple ion species is a single condition that the ion fluid speeds must obey at the sheath edge; but it is insufficient to determine the speed of individual species. It is shown that an instability-enhanced collisional friction, due to streaming instabilities in the presheath, determines this criterion.

[1] S.D. Baalrud, J.D. Callen, and C.C. Hegna, Phys. Plasmas **15**, 092111 (2008).

[2] S.D. Baalrud, J.D. Callen, and C.C. Hegna, Phys. Rev. Lett. **102**, 245005 (2009).

[3] S.D. Baalrud, C.C. Hegna, and J.D. Callen (submitted July 2009); preprint UW-CPTC 09-5 at www.cptc.wisc.edu.

¹This material is based upon work supported under a NSF Graduate Research Fellowship and by U.S. DoE Grant No. DE-FG02-86ER53218. This work was done in collaboration with C.C. Hegna and J.D. Callen.