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Collisionless plasma expansion into vacuum: two new twists on an old problem[1]

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Plasma expansion into vacuum is a generic problem with a broad range of applications. Of particular interest are those regimes where the expanding plasma consists of energetic electrons and cold ions. The expansion is then caused by electron pressure and serves as an energy transfer mechanism from electrons to ions. Collisional plasma expansion is similar to the gas-dynamic expansion, with the fluid description applicable, whereas collisionless plasma expansion requires a kinetic treatment, especially for the energetic electrons. The collisionless expansion is often described under the assumption that the electron distribution is Maxwellian [1]. However, this assumption is not universally relevant, since the expansion may lead to a significant distortion of the electron distribution function. Also, non-Maxwellian electrons may force the quasineutrality condition to break down. This talk presents two problems [2,3] which illustrate the above kinetic effects. The first one is the problem of a magnetic nozzle that transforms an incoming subsonic plasma flow into a supersonic jet. The second is the problem of an expanding nanoplasma (cluster) with a two-component electron distribution. In the nozzle problem, a magnetic mirror, together with the expanding plasma boundary, generates a trapped electron population downstream. This population is decoupled from the plasma source and, consequently, it undergoes adiabatic cooling. The resulting distortion of the electron distribution function is a new element not captured by the usually used Boltzmann relation. In the cluster problem, the key feature is the initial two-component electron distribution with a cold majority and a hot minority both occupying the same volume prior to the expansion. The cluster problem exhibits a breakdown of quasineutrality manifested by a double-layer inside the flow. Both problems are illustrated with closed-form analytical solutions [2,3]. This work was supported by the US DOE NNSA under Contract No. DE-FC52-08NA28512 and Ad Astra Rocket Company. [1] A. V. Gurevich, L. V. Pariiskaya, and L. P. Pitaevskii, Sov. Phys. JETP 22, 449 (1966). [2] A. V. Arefiev and B. N. Breizman, Phys. Plasmas 15, 042109 (2008). [3] B. N. Breizman and A. V. Arefiev, Phys. Plasmas 14, 073105 (2007).

[1] In collabotation with Boris Breizman, Institute for Fusion Studies, The University of Texas at Austin.