

Response to “Comment on ‘Weakly collisional Landau damping and three-dimensional Bernstein–Greene–Kruskal modes: New results on old problems’ ” [Phys. Plasmas 17, 054701 (2010)]

C. S. Ng¹ and A. Bhattacharjee²

¹*Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska 99775, USA*

²*Department of Physics and Institute for the Study of Earth, Ocean and Space, University of New Hampshire, Durham, New Hampshire 03824, USA*

(Received 11 February 2010; accepted 16 March 2010; published online 5 May 2010)

[doi:10.1063/1.3383080]

Based on our reading of his Comment, it seems that the main claim of Grabbe¹ is that in our paper,² we have mischaracterized his previous results³ on Bernstein–Greene–Kruskal (BGK) modes. In order to address this concern, we begin by quoting from Ref. 2 the two citations to his 2005 paper³ (which is Ref. 27 in Ref. 2):

“3D BGK solutions have been constructed under the assumption of a strong magnetic field so that one can use some form of gyro-kinetic or drift-kinetic equation.^{24–27} Solutions have also been obtained in the presence of an infinitely strong background magnetic field.^{28–30}”

“These 3D features seem to be consistent with recent theories that extend the 1D BGK mode to the case with strong magnetic field.^{24–30,58} The physical reason for the existence of such solutions is actually related to the 1D aspect of such a theory, since charged particles are tied to a strong magnetic field like beads to a wire, which reduces a 3D problem to a 1D problem (in the limit of an infinitely strong magnetic field).”

In both the quotations above, we distinguish between solutions with a strong and an infinitely strong magnetic field. It is physically reasonable to argue, for reason of continuity, that if a solution exists in the infinite magnetic field limit, there exists a minimum value of the magnetic field strength over which the solution remains valid, although it may not be easy to pinpoint exactly what that minimum is. In fact, we have not discussed the domain of validity of any of these solutions, since that is outside the scope of Ref. 2. Thus, Grabbe’s claim that we “lumped together” solutions for strong and infinitely strong magnetic fields is without merit.

Our main focus in Ref. 2, as well as its forerunner (Ref. 4), is to determine *exact* BGK solutions in higher dimensions

[three-dimensional (3D) or two-dimensional (2D)] if they exist. By exact solutions, we mean solutions that satisfy the Vlasov equation and the Poisson equation *exactly*, simultaneously, and self-consistently. The 3D and 2D solutions discussed in Refs. 2 and 4 are exact. They are exact in the same sense that the classical one-dimensional (1D) BGK solutions are exact. One may argue that neither the classical 1D BGK solutions nor our 2D solutions exist in a 3D world, and that 3D approximate solutions are more realistic, but it is important to recognize the distinction between an exact and an approximate solution. Grabbe appears not to recognize this distinction. The solutions obtained in previous studies, based on gyrokinetic theory or otherwise, are approximate solutions of the Vlasov–Poisson system of equations in the sense that they rely on asymptotic expansions, and can be considered exact only in the infinite magnetic field limit.

We apologize for our failure to cite Grabbe’s multiple papers on the subject.⁵ This is not because we considered the other papers by Grabbe less important than the one we cited. It is our hope that the interested reader will be able to track his other studies from the paper we have cited.

This response is not supported by research grants from any federal agency.

¹C. L. Grabbe, *Phys. Plasmas* **17**, 054701 (2010).

²C. S. Ng, A. Bhattacharjee, and F. Skiff, *Phys. Plasmas* **13**, 055903 (2006).

³C. L. Grabbe, *Phys. Plasmas* **12**, 072311 (2005).

⁴C. S. Ng and A. Bhattacharjee, *Phys. Rev. Lett.* **95**, 245004 (2005).

⁵C. L. Grabbe, *Geophys. Res. Lett.* **29**, 1804, doi:10.1029/2002GL015265 (2002); **30**, 1797, doi:10.1029/2003GL017894 (2003); *Phys. Rev. Lett.* **84**, 3614 (2000); C. L. Grabbe, in *Developments in Plasmas* (Transworld Research Network, Trivandrum, India, 2000), Vol. 1, p. 89; C. L. Grabbe and J. D. Menietti, *Planet. Space Sci.* **50**, 335 (2002).