Comment on "Kinetic Simulations of Magnetized Turbulence in Astrophysical Plasmas"

In a recent Letter, Howes *et al.* [1] (HEA) claim (i) that reported gyrokinetic simulations simultaneously capture both magnetohydrodynamic (MHD) cascade and small scale kinetic plasma dynamics and (ii) that solar wind turbulence remains at low frequencies at all scales, is well described by gyrokinetics, and mainly dissipates through kinetic Alfvén waves (KAWs). This Comment clarifies and corrects these claims.

First, standards for identifying an inertial range power law are stretched dramatically by HEA. Nevertheless, HEA claims to see "spectral slopes ... consistent with scaling predictions for critically balanced turbulence." This is based on numerics that span a 32:1 ratio of largest ($L_\perp$) to smallest resolved scales. Non-MHD behavior is reported at wave numbers $kc/\omega_{pi} \sim 1$ near the ion inertial scale, i.e., $kL_\perp \sim 10$ or 2.5 (Figs. 2 and 3 in [1]). The larger unresolved cascade is represented by driving at the lowest k's. There can be no more than a factor of 2–4 in k in which one might see "a scaling consistent with $k_\perp^{-5/3}$" stated to be "as expected for critically balanced . . . turbulence," and "the first demonstration of an MHD turbulence spectrum in a kinetic simulation."

The computed low-k spectral form is surely not due to self-similar interactions as suggested by a straightforward reading of HEA. Whatever the origins may be (e.g., forcing, box size, etc.), no conclusion can be drawn about MHD scaling laws in this computation. HEA actually report two different spectral laws for $B_\perp$ at low k—one shallower than $-5/3$ (Fig. 2 of [1]) and one steeper (Fig. 3 of [1]).

In turbulence simulation, accurate portrayal of self-similar spectra requires $>10^3$ degrees of freedom per dimension [2], and thus the demonstration attempted by HEA is difficult. Similar challenges are addressed in fully electromagnetic plasma particle-in-cell computations [3] of inhomogeneous turbulence driven by a large scale sheared magnetic field, a model that includes more small scale kinetic plasma effects than gyrokinetics. HEA's claim (i) is clearly questionable.

Second, HEA use gyrokinetics to compute an enhanced electric field at $kc/\omega_{pi} > 1$, as reported in the solar wind [4]. Based on this, HEA conclude [claim (ii)] that gyrokinetics correctly represents the solar wind dissipation range and that KAWs are the dominant kinetic description at $kc/\omega_{pi} > 1$. It is, however, readily established that the Bale *et al.* result does not require dissipation, or KAWs. Figure 1 documents very similar electric field spectral enhancements in compressible 3D [5], 2.5D, and 1D Hall MHD (D = dimension) with a mean magnetic field. It is found even in cases with no mean magnetic field (not shown), e.g., ideal incompressible [6], and compressible [5] 3D Hall MHD. All that is required is the dispersive character of Hall MHD, a simple fluid model, and not gyrokinetics, full kinetic plasma physics, or dissipation of any type. Thus, one cannot on this basis rule out contributions of whistler physics in the solar wind observations. Nor can one rule out truly zero frequency eddy-type plasma dynamics that are not described by KAWs or whistlers, or any scheme that relies on a linear dispersion relation. Clearly, claim (ii), that there is [1] "compelling evidence that the observed breaks in the spectra are caused by a transition to a KAW cascade," does not follow. Finally, solar wind observations [7–9] suggest physical processes that are not represented in any obvious way in gyrokinetics. Thus, the simplifications suggested by HEA are not readily supported.

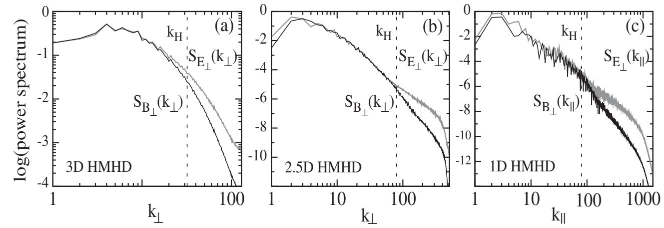

FIG. 1. Hall MHD (256^3, 3D; 1024^2, 2.5D; 4096 1D). Electric spectrum is enhanced relative to magnetic spectrum at $k > k_H = \omega_{pi}/c$. A kinetic model is not required.

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[1] G. G. Howes *et al.*, Phys. Rev. Lett. **100**, 065004 (2008).
[2] P. D. Mininni, A. Alexakis, and A. Pouquet, Phys. Rev. E **77**, 036306 (2008).
[3] K. Bowers and H. Li, Phys. Rev. Lett. **98**, 035002 (2007).
[4] S. D. Bale *et al.*, Phys. Rev. Lett. **94**, 215002 (2005).
[5] P. Dmitruk and W. Matthaeus, Phys. Plasmas **13**, 042307 (2006).
[6] S. Servidio *et al.*, Phys. Plasmas **15**, 042314 (2008).
[7] J. W. Bieber *et al.*, J. Geophys. Res. **101**, 2511 (1996).
[8] R. J. Leamon *et al.*, Astrophys. J. **537**, 1054 (2000).
[9] O. Alexandrova *et al.*, Planet. Space Sci. **55**, 2224 (2007).

