Comment on “Oblique Double Layers: A Comparison between Terrestrial and Auroral Measurements”

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Comment on "Oblique Double Layers: A Comparison between Terrestrial and Auroral Measurements" by C. Charles, R.W. Boswell, and R. Hawkins

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Charles et al.[1] compared the features of **U**-shaped **d**ouble **l**ayers measured in the **a**uroral[2] plasma (AUDLs), with that in the **l**aboratory Helicon Plasma Device (HPD), called here as LUDLs. While the comparison treats some basic properties of double layers well, it creates misperceptions about the structure of the AUDLs in the auroral **r**eturn **c**urrent **r**egion. Further, Charles et al.[1] use the phrases 'weakly diverging' and 'weakly converging' to describe the magnetic field (**B**) in both the HPD and the aurora. In HPD the scale length (L_B) of the diverging **B** is smaller than the ion Larmor radius (ρ_i) while in the auroral plasma L_B is several orders of magnitudes larger than ρ_i. Thus, describing **B** in HPD weakly diverging is incorrect and it obscures the physics of the LUDL formation in HPD, as we explain below.

Displaying Figs. 1a (AUDL) and 1b (LUDL) side by side and their labelings[1] might heighten the visual similarities between them, but comparing them is misleading. An AUDL with electric fields *diverging* away from the central region of the U-shaped potential structure occurs in the auroral **d**ownward **c**urrent **r**egion[2] (DCR). Fig.1a *incorrectly* shows a density cavity below the bottom of the AUDL, opposite to the magnetospheric side. The dense ionospheric plasma lies below the bottom of the AUDL in the DCR and the density cavity extends upward towards the magnetosphere. The key to the formation of an AUDL in the DCR is the continuity of the current, requiring upward acceleration of electrons in the low-density cavity[3], which charges positive with respect to the ionospheric dense plasma. In contrast, LUDL in HPD is a current-free structure[1], in which the density gradients are opposite to that in an AUDL. Furthermore, indicating 'auroral cavity' in their Fig. 1a and 'plasma expansion' in Fig. 1b and showing the downward ion fluxes J^+ in both create the misperception that the downward plasma expansion accompanies the AUDL. In contrast, an AUDL moves upward[2] riding on top of an upward expanding ionospheric dense plasma.[4]

Charles and coworkers[5] have suggested that LUDL in HPD forms due to a reduction in the plasma density when the dense plasma generated in the **s**ource chamber expands into the diffusion chamber. The two-dimensional measurements reported in Refs. 1 and 6 reveal that the LUDL forms because of the HPD geometry, which involves *sudden* transition in the cross section of the expanding plasma and *abruptly* diverging **B** from the source to the diffusion chamber. The magnetic- field scale length in HPD is $L_B < \rho_i \geq 7$ cm and $L_B >> \rho_e \sim 0.16$ cm, the electron Larmor radius. Also the ion transit time across the axial distance in the LUDL is less than the ion cyclotron period while just the opposite is true for the electrons. Thus, ions are nearly unmagnetized while electrons are highly magnetized in the LUDL structure. Upon exiting the source chamber, the highly magnetized electrons follow the diverging **B** while the unmagnetized ions tend to move along the axial direction. This creates space charge, generating electric fields, $\mathbf{E}_{\perp s}$, perpendicular to the axial direction, z, near the *transition* region from the source to the diffusion chamber. The electron and ion flows and $\mathbf{E}_{\perp s}$ self-consistently adjust giving a conical density structure, as recently reported in Ref. 6. Away from the transition region, $\mathbf{E}_{\perp s}$ is shorted out in the diffusion camber, converting the perpendicular potential drop ($\varphi_{\perp 0}$) associated with $\mathbf{E}_{\perp s}$, into parallel potential *drops*, both within the LUDL, directly downstream of the source chamber, and outside with opposite polarities. *The latter is not shown* *in Fig. 5 of Ref. 1 but it is in Fig. 2 of Ref. 6.* Thus, the LUDL in HPD is a response of the plasma in the diffusion-chamber to the generation of the source electric field $E_{\perp s}$. The measured densities and electron temperatures reported in Ref. 6 give $\varphi_{\perp 0} \sim (T_e/e) \ln (n_{max}/n_{min}) \sim 25$ V, where n_{max} and n_{min} are the maximum and minimum densities supporting the sharp *transverse* density gradient near the transition. This mechanism for the LUDL cannot operate in space and astrophysical plasmas, where the condition $\rho_e << L_{\mathbf{B}} < \rho_i$ cannot be met. In HPD, **B** diverges abruptly such that $\rho_e << L_{\mathbf{B}} < \rho_i$, an essential factor for the formation of measured LUDL.

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