PIC Analogues of Sharp, Perpendicular Electric Fields Observed in Magnetopause Current Layers

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Full PIC simulations in guide field and anti-parallel geometries have been surveyed for **E**lectric **F**ield **E**nhancement EFE signatures that are consistent with those reported by Mozer et al, 2004 and discussed by Scudder et al 2005. Narrow and strong perpendicular electric fields are routinely found in the PIC codes just behind the separatrices on the accelerated exhaust side of the flow pattern. These structures also occur in the coalescence geometry and are probably also related to the electrostatic eigenfunctions of the tearing process. These structures appear to be part of a larger pattern, slightly displaced from the separatrices emanating from the separator and usually seen to the edges of the simulations (all performed with OPEN boundary conditions as discussed by Daughton at this conference). The parallel electric field in EFE's are much weaker than the perpendicular fields, although present at the 1% level, similar to the observed EFE's. EFE's in nature are so abrupt that there are no direct plasma measurements within them. However, indirect arguments place their size at or below the electron skin depth and one measurement of these structures infers them to have a half width of 7 Debye lengths, comparable to the thermal electron gyroradius. The logarithmic derivative of the perpendicular electric field in the PIC codes determines a spatial scale $L_{E_\perp}$ suitable for comparison to the local thermal electron gyroradius, ρ_e. Routinely $\rho_e / L_{E_\perp} \gg 1$ at the edges of these structures, whose overall half widths are comparable to ρ_e. The EFE layers represent a considerable impediment to a simple guiding center description of the electrons. The EFE $E_\perp$ is 30% different than the electric inferred from the electron's bulk motion alone. Accordingly this, electric field structure cannot be reproduced by a simple Hall description; the heating of the electrons caused by the interaction with the EFE's also makes important pressure gradient modifications to the perpendicular electric fields in these layers that will be demonstrated. Since all these results have been obtained from simulations with OPEN boundary conditions, there is no contribution to these structures from recirculating electrons that are unavoidably present in periodic simulations.

The pressure tensors of the PIC electrons are severely disrupted from cylindrical symmetry by these EFE layers with such abrupt edges. This disruption is not confined to the separator proper, there being significant agyrotropy both at the separator and out along the separator for a presently unknown distance – but larger than boxes that presently can be afforded with Open Simulations. The PIC agyrotropies are shown to be correlated with the product of the Lorentz force ratio in these structures times a theoretically derived function of $\rho_e / L_{E_\perp}$. The PIC "observables" of the pressure agyrotropy, the Lorentz force partition and the ratio of scales will be illustrated to follow this theoretical profile. In this way we confirm that these sharp electric structures can change the thermal energy of the electrons, since there is insufficient time for the thermal electrons to ExB drift in these layers – a result that explains why the electric field in these layers in not simply that caused by the electron drift. When the pressure tensors are most deformed from cylindrical symmetry in the PIC codes we also show evidence that the principal axes of the pressure tensor transverse to the magnetic field are increasingly aligned with the direction of $\hat{\mathbf{E}}_\perp$ as expected with the direct heating role it represents. Contributions of these layers to out of simulation plane reconnection electric field will also be discussed.

Mozer, F.S. et al. , *Geophys. Res. Letts*, 31, L15802, 2004.
Scudder, J.D and F.S. Mozer, *Phys. of Plasmas*, 12, 092903, 2005.