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Auroral Electrons Trapped and Lost: A Vlasov Simulation Study

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Model

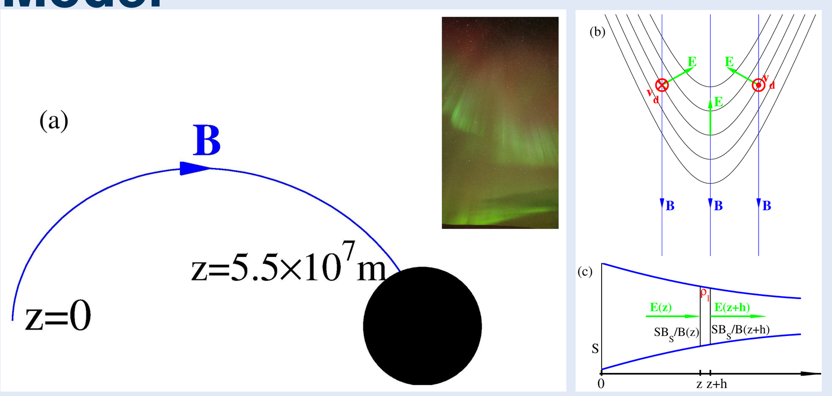

Figure 1: (a) A field line for the $L = 7$ shell. (b) Cross section of an auroral arc. (c) Flux tube cross section z dependence.

The Vlasov equation for our system is

$$\frac{\partial f}{\partial t} + v_z\frac{\partial f}{\partial z} + \frac{1}{m}\left(qE - \mu\frac{dB}{dz} + ma_g\right)\frac{\partial f}{\partial v_z} = 0. \qquad (1)$$

The electric field is computed according to

$$\frac{d}{dz}\left(\frac{B_S}{B}E\right) = \frac{1}{S\epsilon_0\epsilon_r}\sum_s q_s \int f_s(v_z,\mu)\,d\mu\,dv_z, \qquad (2)$$

Initial state

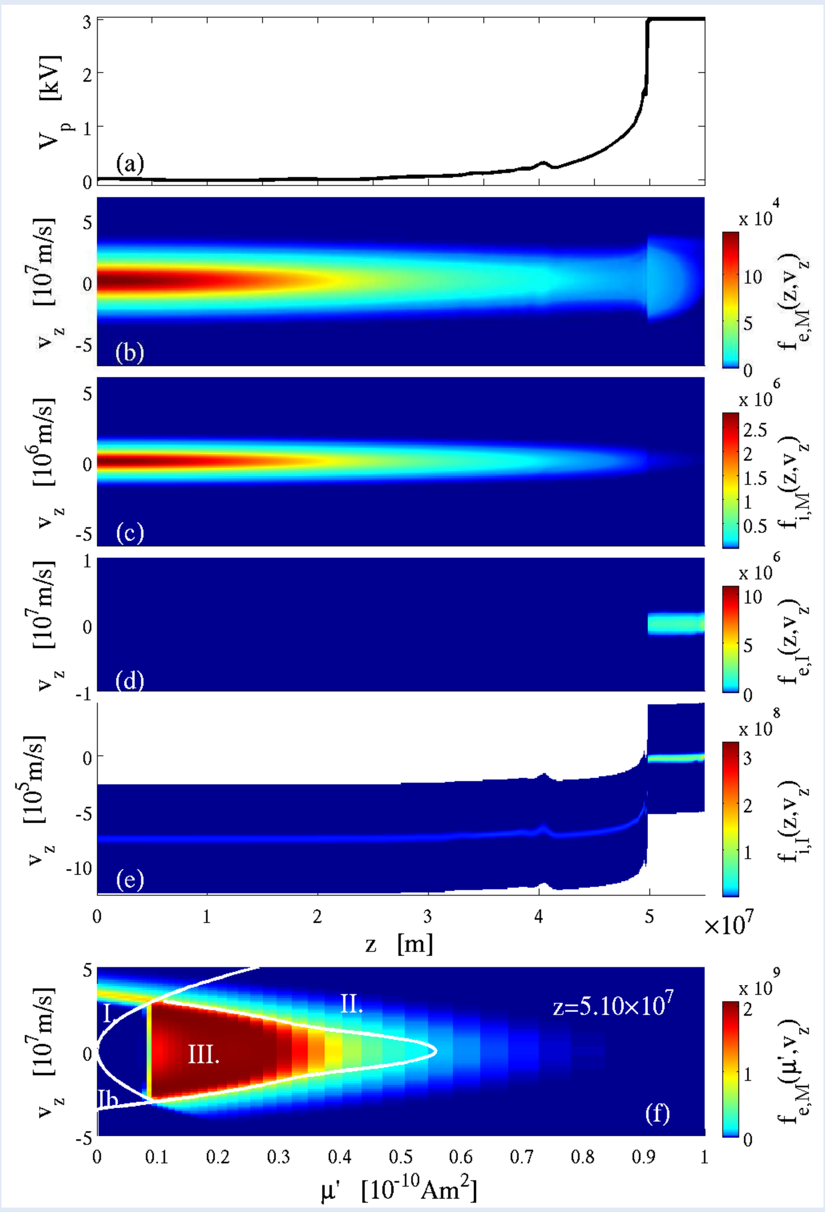

Figure 2: Initial state of for the numerical experiments.

Numerical experiments

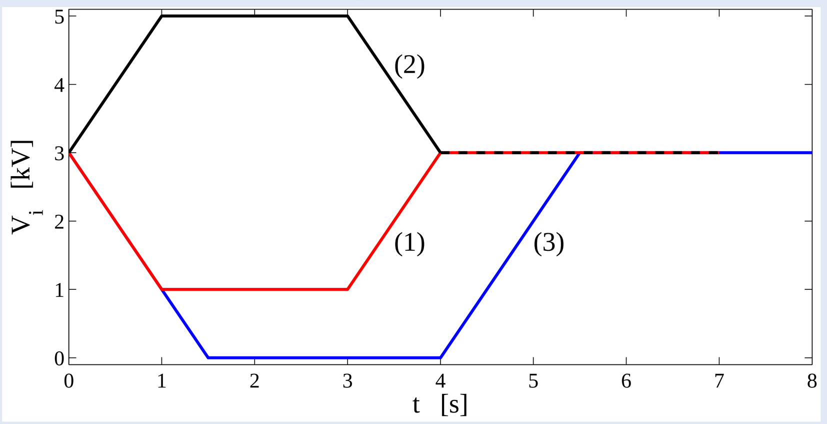

Figure 3: The total voltage imposed on the simulated flux tube as a function of time for the three numerical experiments.

Experiment 1

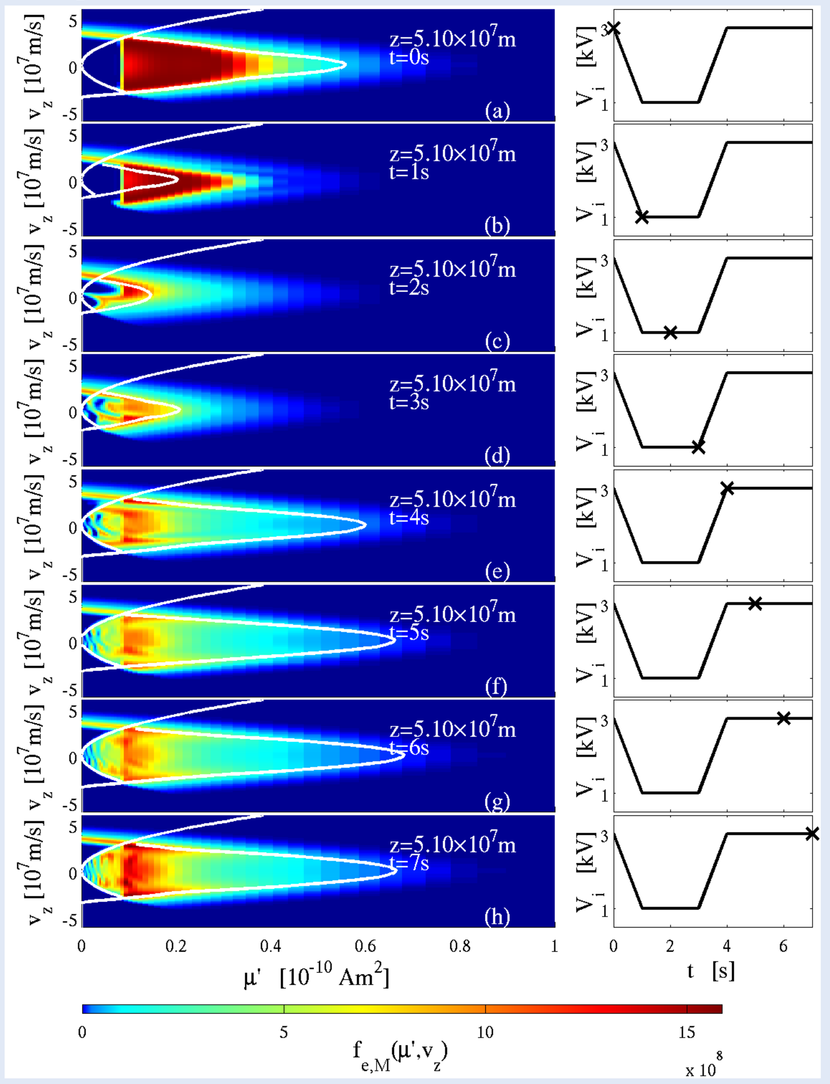

Figure 4: Phase space density $f_{e,M}(\mu', v_z)$ in experiment 1 at $z = 5.1 \times 10^7$ m (on per second). To the right the time is marked on a diagram of the total voltage.

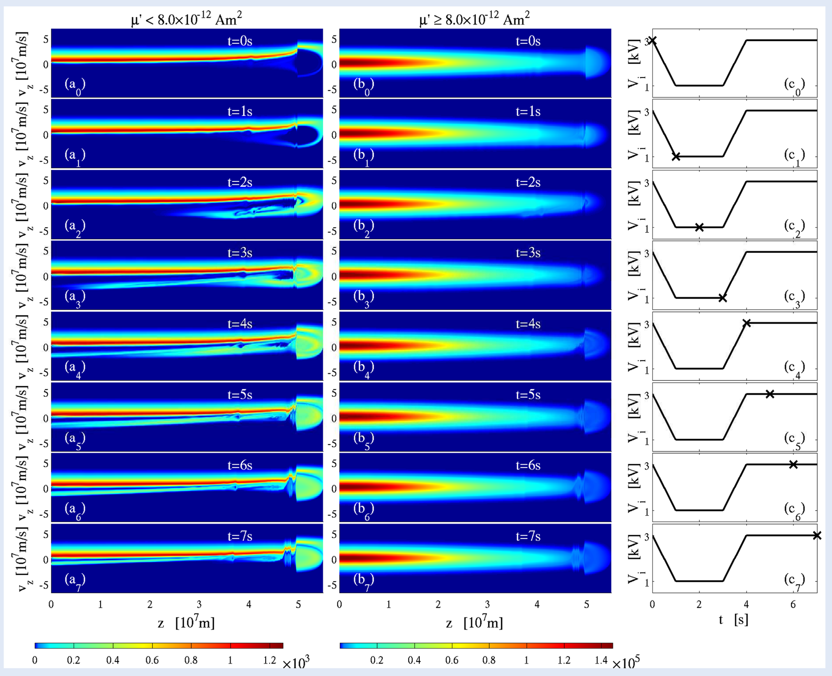

Figure 5: Partial phase space density $f_{e,M}(z, v_z)$ of magnetospheric electrons for experiment number 1.

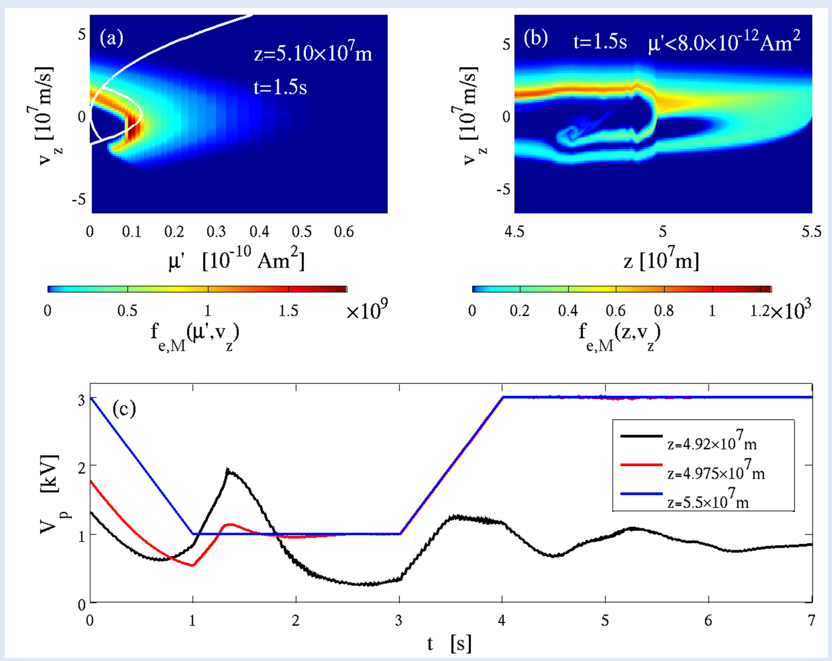

Figure 6: Illustration of the effect of a time dependent potential profile on the particle distributions.

Experiment 2

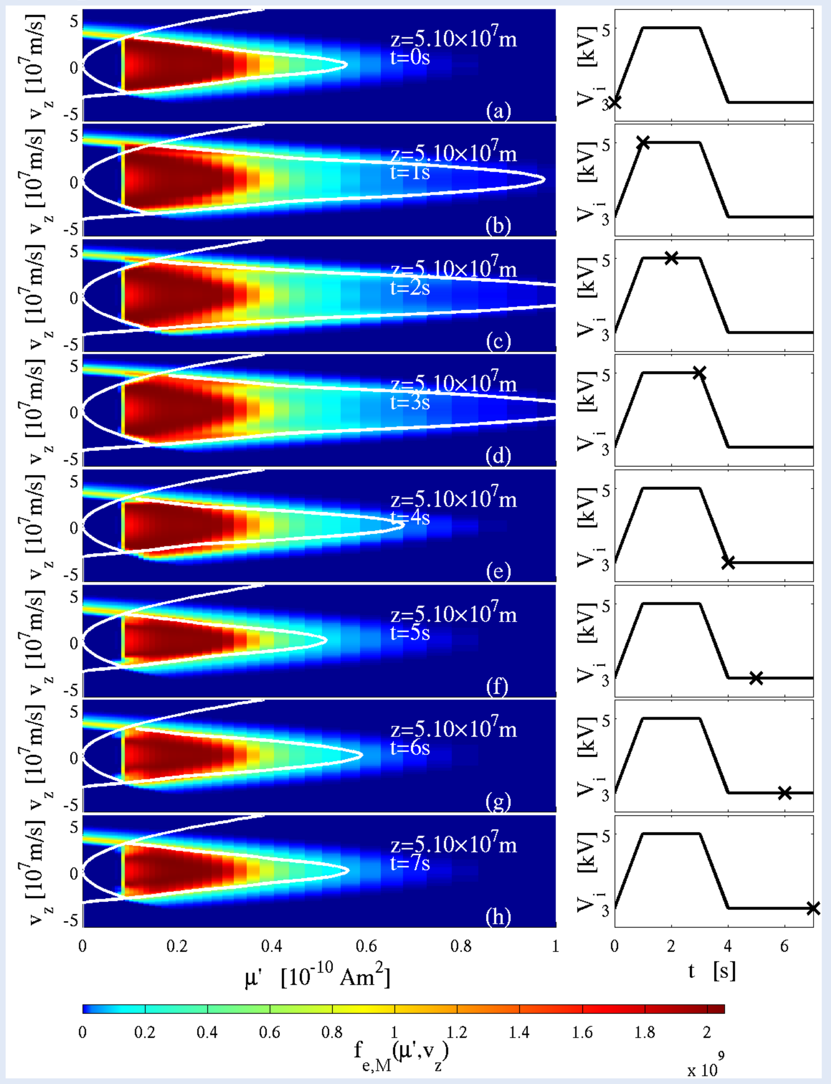

Figure 7: Phase space density $f_{e,M}(\mu', v_z)$ in experiment 2.

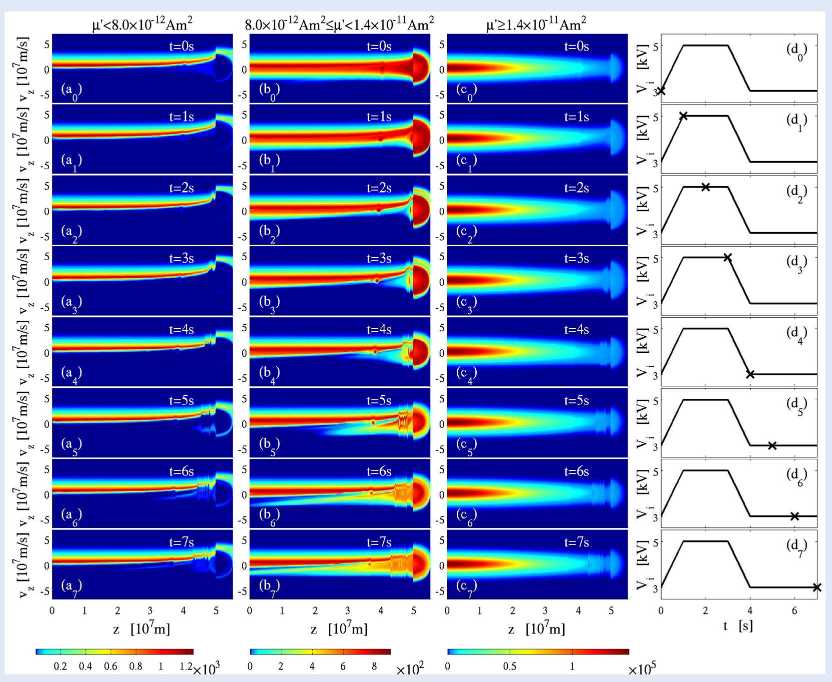

Figure 8: Partial phase space density $f_{e,M}(z, v_z)$ of magnetospheric electrons for experiment number 2.

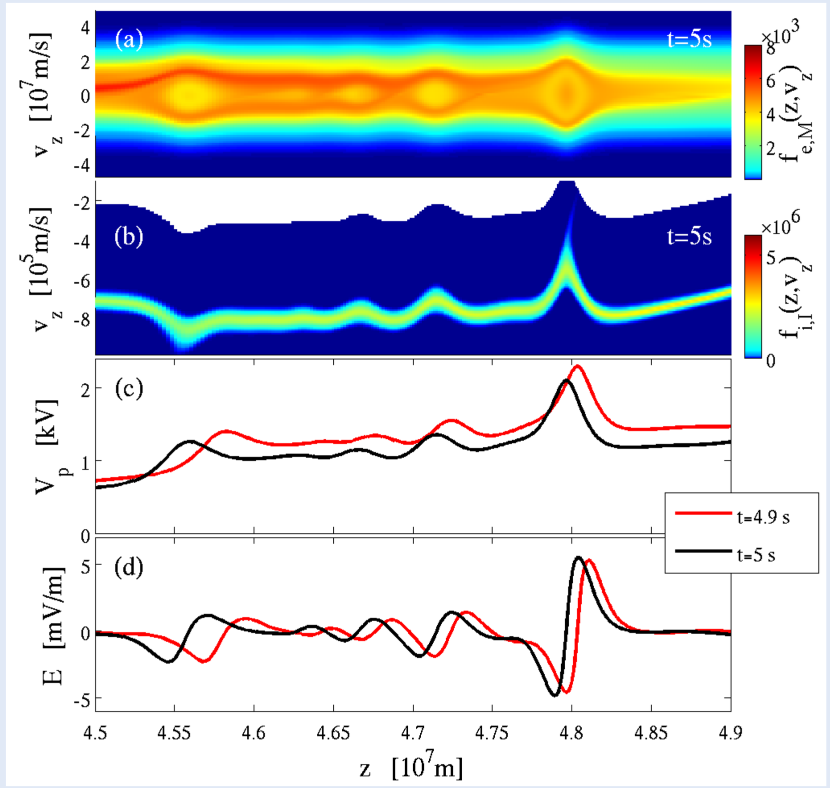

Figure 9: Waves in experiment 2.

Experiment 3

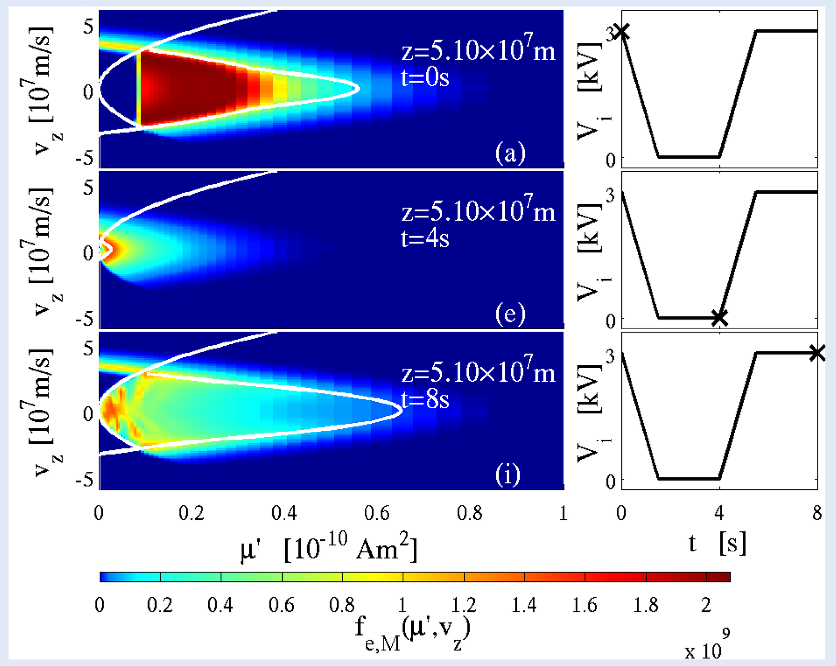

Figure 10: Phase space density $f_{e,M}(\mu', v_z)$ in experiment 3.

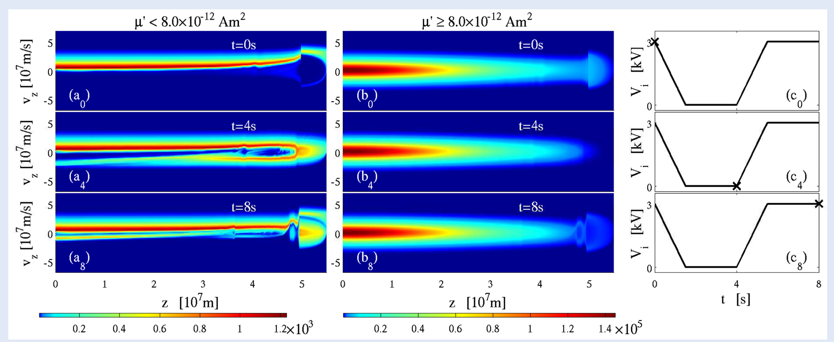

Figure 11: Partial phase space density $f_{e,M}(z, v_z)$ of magnetospheric electrons for experiment number 3.

Comparing the experiments

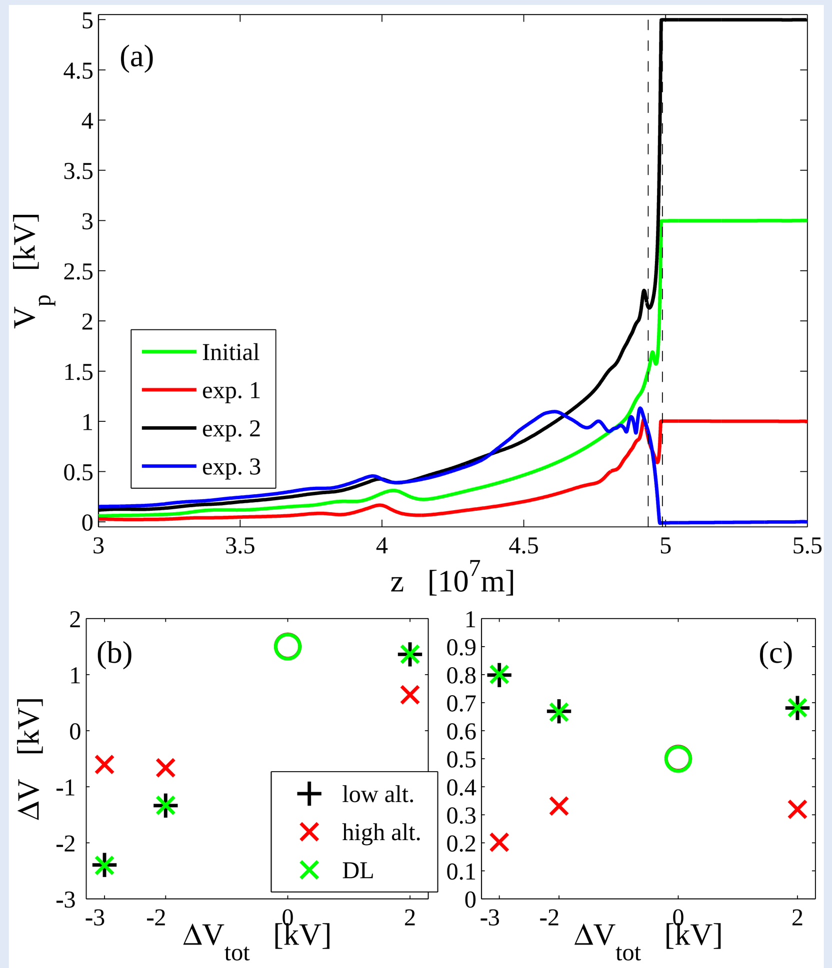

Figure 12: Distribution of ΔV. (a) Plasma potential as a function of z for the initial state (green) and the mean of the plasma potential during 0.1 s starting when the respective target voltages were first reached. The left vertical dashed lined is located at $z = 4.94 \times 10^7$ m where the initial plasma potential was 1500 V. The right vertical dashed lined is located at $z = 4.99 \times 10^7$ m. (b) The part of ΔV below ("+") and above (red "×") $z = 4.94 \times 10^7$ m and the part across the double layer (green "×"), all plotted versus the total ΔV. (c) The same quantities as in (b), normalised to the total ΔV.

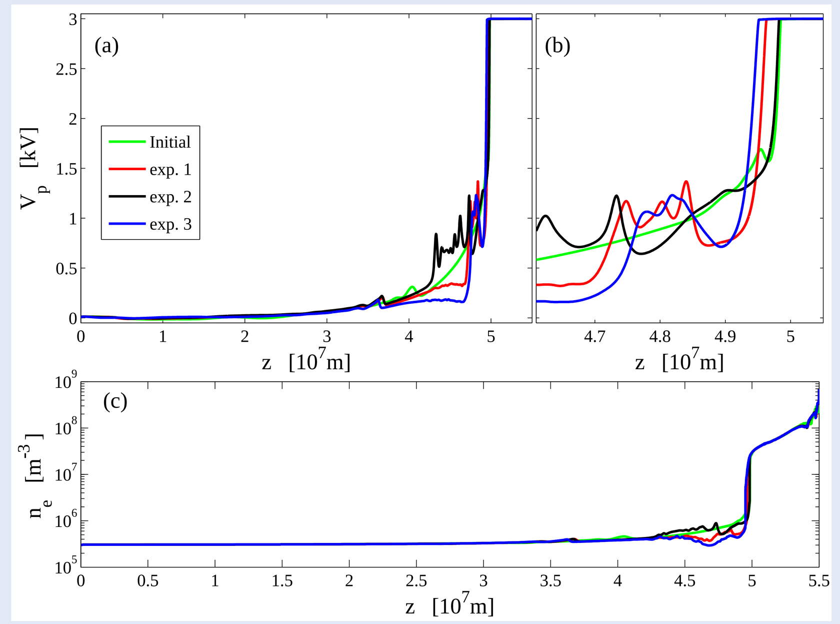

Figure 13: Final state. (a) Plasma potential as a function of z at the end the three experiments (red, black and blue) are shown together with the initial state (green). (b) Closeup or the plasma potential around the double layer. (c) Plasma density as a function of z at the end the three experiments (red, black and blue) and the plasma density of the initial state (green).

Conclusions

- We use a 1d2v electrostatic Vlasov simulation code [Gunell et al., 2013] to study electron trapping and release processes on auroral flux tubes. Fortran source code of the simulation program is available at <http://www.herbertgunell.se/software.php>.
- The history of the acceleration voltage affects the distribution function of the trapped electrons.
- Measurements of the electron distribution functions could tell us something about the recent history of the acceleration voltage.
- Most of the change in the acceleration voltage is assumed by the double layer.
- For a quickly decreasing voltage the double layer changes polarity.
- Phase space holes are created in these numerical experiments.
- The double layer position exhibits hysteresis phenomena.

Acknowledgements

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References

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