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Nonlinear Processes in Geophysics Discussions

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Interactive comment on “Ion acceleration at dipolarization fronts associated with interchange instability in the magnetotail” *by* Chao Sun et al.

Chao Sun et al.

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We greatly thank the reviewer’s helpful comments and suggestions on our manuscript, which are very useful for us to improve our manuscript. Following are the reply to the suggestions.

Major comments: In order to set the value of the electric field in the simulation similar to that observed by in-situ measurements, the authors make a strong assumption on the initial condition. This assumption has to be justified by physical arguments. Since the set-up is not an equilibrium, the author should provide theoretical evidences that the configuration they are considering can dynamically form, or is at least likely to be present, in the magnetotail. Moreover, I suggest that the authors plot the initial profiles

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Discussion paper

of the most important quantities as a function of "x" in the case of the quasi-stationary equilibrium and in the case used for the Hall MHD simulation.

Reply: The initial condition used in our manuscript is based on one equilibrium equation. We plot the _0,B_z and E along the y = -0.6.

2) What boundary conditions are used for the particles? What happens to a particle that reaches the "x" or "y" boundary? Why is there an accumulation of energetic particles at y=0? This doesn't seem to be a physical effect.

Reply: As for the boundary condition for the ions, they remain stationary at the boundary once they hitting the simulation boundary in y direction. In our manuscript there are two vortex flow pattern as a consequence of the earthward flows coexisted with the tailward flows. The particles are concentrated at y=0 because of the vortex flow pattern.

3) The parameters used for the Hall MHD and the test-particle simulations must be specified. How many grid cells where used in the Hall MHD simulations? Are the electric and magnetic field coming from the Hall MHD simulation interpolated in space and time to advance particle evolution? How is this interpolation done? Which method is used for integrating the trajectories? How does the time step used to compute particle trajectories compare with the ion gyroperiod and with the time unit of the simulation? What is the direction of the test-particles initial velocity? How does the initial Larmor radius compare with the grid size?

Reply: Thank you. The numbers of grid cells in x and y directions are set 301 and 201, respectively. The magnetic and electric fields of ions were calculated by PIC (Particles in Cell) method. In our simulation, we adopt the MHD time step as the test particle simulation time step. At each time step, we use the fourth order Runge-Kuta to solve the equation of motion. The direction of the initial velocity of the ion is random. Under the condition we chose, the initial Larmor radius is 522km which is 0.082 in dimensionless unit. It occupies 6 and 11 grid points in x and y direction respectively.

4) In order to show an actual energization of the ions, the author should provide the PDF of particle energy at the beginning and at the end of the simulation.

Reply: The initial power law energy distribution F$\sim$(1+h/(κT_0))^(-κ-1), which is similar to kappa distribution.

5) Are the particle free to move along z? Due to the 2D field, particles do not see any field variation along z. This rules out processes such as pitch-angle scattering along Bz which can influence particle transport. The author should discuss this limitation.

Reply: Thank you. The corresponding context has been added in the modified manuscript.

14: The authors state that "It has been shown . . . in the magnetotail". Can they please provide a reference for this statement?

Reply: It has been modified in the new manuscript. 41: "SC" has not been defined previously.

Reply: It has been modified in the new manuscript.

64: Maybe substitute "along" with "by".

Reply: Thank you.

70: Isn't it better to put a full stop rather than a comma after ". . . that ahead of it"?

Reply: Thank you.

96-100: "Since the DF is produced by temporal. . . in the magnetotail". I don't see the connection between the sentences before and that after the comma. For example, wouldn't it be more meaningful to study this problem using a truly self-consistent PIC code?

Reply: The sentence has been rephrased in the modified manuscript.

108-109: What does it mean that ions trajectories are tracked "backward" in time?

Reply: In the simulations, we run the simulation with positive time step then check the time history of the trajectories of selected particles.

115-117: Please explain in more details where the gravity term comes from.

Reply: Interchange instability is considered as a possible generation mechanism for the multiple Dipolarization fronts, which have been observed in the near-Earth region in many literatures. One can imagine a picture that as a fast Earthward flow approaches the Earth, it would be braked by the ambient plasma. In the braking region, the tailward gradient of thermal pressure increases and meanwhile the earthward magnetic curvature force increase, which consequently leads to a tailward force. This tailward force enables Earthward fast flows decelerate initially and brake finally in the near Earth plasma sheet. In conjunction with the tailward gradient of plasma density due to the flow braking, the total force brings forth interchange instability in the braking region.

125: "gx" is not contained in Equation 1.

Reply: The typo error has been corrected in the modified manuscript.

133: Where does "p/6" come from? What is the definition of "beta"?

Reply: Electron pressure pe is taken as p/6, because the proton temperature is 5 times that of electron temperature. β is plasma beta.

218-220: At what time is Figure 3 plotted?

Reply: Figure 3 plot the PDFs of total particle energy at t = 286s.

221-231: This part on the variation of the pdf along x is kind of obscure to me. What is it meant to show?

Reply: We plot Figure3 to get a better sense of the distribution of the ions.

331 (Figure 7): How are w, w1 and w2 defined?

Reply: We used the formula w_1=ΔE_x·Δx and w_2=ΔE_y·Δy to calculate w_1 and w_2. W is the kinetic energy of the particle given by 1/2 mvˆ2.

Please also note the supplement to this comment:
https://www.nonlin-processes-geophys-discuss.net/npg-2018-43/npg-2018-43-AC2-supplement.pdf

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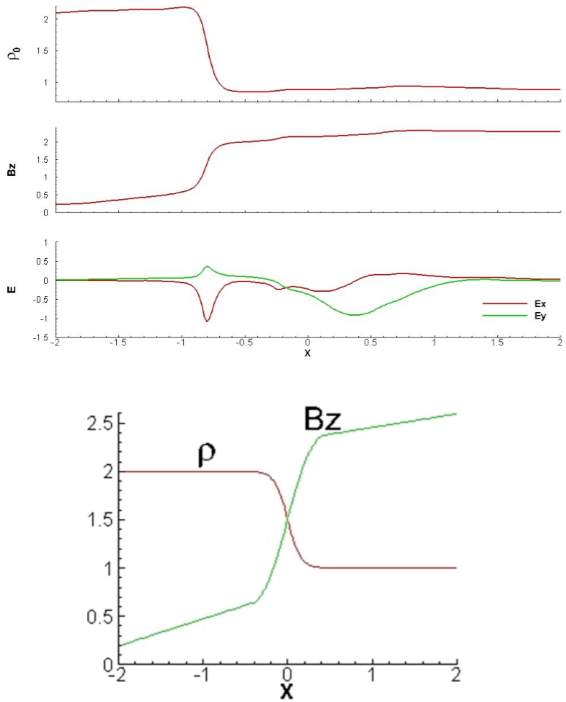

Fig. 1.