

Ann. Geophys. Discuss., referee comment RC1
<https://doi.org/10.5194/angeo-2020-89-RC1>, 2021
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Comment on angeo-2020-89

Anonymous Referee #1

Referee comment on "Ion distribution functions in magnetotail reconnection: global hybrid-Vlasov simulation results" by Andrei Runov et al., Ann. Geophys. Discuss.,
<https://doi.org/10.5194/angeo-2020-89-RC1>, 2021

The authors carried out a comprehensive analysis on Vlasiator simulation results of magnetotail reconnection, focusing especially on the ion distribution functions and their comparison with spacecraft observations. Although we cannot expect a full consistency between the simulated and observed ion distributions (for example, the phase-space lacunae at the pitch angle of 45 degrees is indeed very puzzling), the simulation results indeed show some of the observational features, which in some sense validates the Vlasiator model and provides a useful tool to understand the particle dynamics associated with the reconnection process. I believe that the paper is overall a good addition to our current knowledge of magnetic reconnection, although I have some minor comments listed below.

Specific comments:

1. Page 14, lines 11-19. The authors interpret the ion velocity shift in the x and y directions (shown in Figures 6j and 6o) as 'gyration in the increasing northward Bz'. However, this interpretation is inconsistent with the magnetic field configuration in Figure 6a, in which the magnetic field is in the earthward direction (with nearly zero Bz) at the location of the light blue virtual probe.

I would propose an alternative interpretation. Any duskward-moving ion at the virtual probe has its instantaneous gyro-center to the south of the probe, which indicates the possibility of Speiser-type meandering orbits. On the other hand, the dawnward-moving ions with gyrocenters further northward can only stay in the northern hemisphere. Therefore, the higher fluxes in the duskward rather than dawnward direction could be naturally understood by the higher density at locations closer to the neutral sheet.

In my understanding, the simulated ion distributions could be better explained by the model of Zhou et al. (2016, JGR, 'Understanding the ion distributions near the boundaries of reconnection outflow region'). As reconnection happens, the ions originally in the plasma sheet are picked up by the reconnection-associated E_y and B_z fields to move downstream away from the reconnection site. On top of this convective bulk motion, the pickup ions also keep meandering across the neutral sheet. These meandering ions must exhibit duskward and downstream directed velocities when they reach the off-equatorial boundary of the reconnection exhaust.

2. Page 16, First paragraph. The authors state that 'Fermi acceleration continues during the tailward convection of the plasma'. I don't get this picture, since my understanding of the Fermi acceleration is that requires two magnetic mirrors moving towards each other. But do we have magnetic mirrors tailward of the reconnection site?

Technical corrections:

1. Page 10, line 15: ' $12.5 R_E$ ' should be ' $-12.5 R_E$ '.

2. Figure 5, left panel: I don't quite understand the label of the horizontal axis, ' $V_v \text{ perp } B$ '.