

## **Comment on egusphere-2022-420**

Anonymous Referee #1

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Referee comment on "Spatial filtering in a 6D hybrid-Vlasov scheme to alleviate adaptive mesh refinement artifacts: a case study with Vlasiator (versions 5.0, 5.1, and 5.2.1)" by Konstantinos Papadakis et al., EGU sphere,  
<https://doi.org/10.5194/egusphere-2022-420-RC1>, 2022

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The manuscript (MS) discusses an important topic – the first application of AMR in Vlasiator with a goal to enable fully 6D simulations. With a few exceptions, the text is well written. The MS, however, needs to be further improved in order to demonstrate the effect of spatial filtering on simulation results in more detail.

Major concerns:

- Fig. 3 and Fig. 8 show numerical artefacts in XY plots but they do not show the AMR mesh. It is not clear how these are related exactly. The MS mentions the AMR mesh can be recovered from these figures (line 143). No, that is not enough. Please show the AMR mesh explicitly.
- Also, why do the authors show smoothed ("fixed") solutions for Fig.8 but not Fig.3? This is confusing. If you show numerical issues, it makes sense to show how you fix them everywhere.
- What region exactly do those insets in Fig. 8 represent? Why does one show coarse cells and the other shows fine cells while they seem to represent the same AMR mesh with and without filtering?
- What sense does it make to show Fig. 8(d,f) if they cannot be compared to similar unfiltered profiles?
- Given all the above, please show unfiltered and filtered plots side by side for comparison, together with the AMR mesh. Fig 3 and Fig.8(c-f) do not carry much information unless you show their counterparts next to them.

Overall, my major concern is that it is not clear at this point if the authors have “cracked” the problem or not. This spatial filtering may be good enough to regularize the bow shock boundary, but this procedure may result in modifying the global solution considerably. The only way to verify that is to also show a reference solution on a fine uniform mesh. I don’t see those. It looks to me that the MS shows either unfiltered AMR solutions or filtered AMR solutions, without comparing them side by side or showing uniform mesh solutions next to them.

- Lines 39-40: I am actually surprised that Vlasiator uses a semi-Lagrangian scheme in configuration and velocity space. These schemes are known to enhance numerical diffusion due to their inherent need to map Lagrangian particles back to the mesh. Please comment on diffusion effects they cause, compared to high-order Eulerian approaches. I understand that the Lagrangian step preserves positivity and is conservative. However, it is highly diffusive too, which is not discussed here.

Minor Comments:

- Lines 100-105: How is Eq.6 related to numerical filters actually used in the MS? Either strike this equation out or explain how it is supposed to be used. Is ‘j’ the imaginary unit? Is this formula supposed to be used in Fourier transforms? Show that exactly in Eq. 7.
- Line 5: strike out ‘resolution induced’
- Line 14: rephrase with ‘3 dimensions .... space’.
- Line 19: strike out ‘which in practice’
- Line 21: there’s no Gauss law here ( $\text{div}E = 4\pi\rho$ )
- Lines 30-31: Lapenta (2012) is not appropriate for referencing the PIC method in general.
- Line 134: replace ‘artificial step’ by ‘density step’.