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Interactive comment on "MMS observations of energetic oxygen ions at the low-latitude duskside magnetopause during intense substorms" *by* Chen Zeng et al.

Anonymous Referee #2

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The manuscript by Zeng et al., on "MMS observations of energetic oxygen ions at the low-latitude duskside magnetopause during intense substorms" shows that energetic oxygen abundance in the magnetopause is regulated by the IMF By direction, although IMF Bz plays a minor role. The manuscript is mainly well written and organized. However, the conclusions are not well supported by the observations on my opinion. I think the manuscript has potential to be published in Annales Geophysicae after considering the following comments and suggestions:

Major comments:

1. One of the conclusions of the manuscript is that particles are transported from the

tail towards the day side. To make such a conclusion more rigid one should show the anisotropy of the particle distributions, which would indicated that particles move from the tail towards the dayside. The oxygen ions could also come from other sources such as inner magnetosphere (filled directly from the nightside aurora into the ring current), from the diamagnetic cavities/cusp (e.g. Slapak et al., Ann. Geophys. 2013, 10.5194/angeo-31-1005-2013).

2. I am not sure if one could make firm conclusions about dependence on the IMF Bz, if from 31 events only 6 events were observed during northward IMF. On my opinion the statistics is too poor for that.

3. The "intense substorms" are discussed in this study. Were these substorms associated with magnetic storms? Or these are pure substorm events? What is the reason for choosing intense substorms? Inlcuding other substorms may increase the statistics on the IMF dependence.

4. Introduction, first two paragraphs can be merged as they contain repeating information about acceleration during dipolarizations. The second paragraph is not completely logical. It would make more sense to describe acceleration of O+ starting from the polar regions, then lobe, dipolarizations and then discuss drift. The sentence in lines 43-45 discussing acceleration of electrons during dipolarizations is not really needed as there is a number of references about acceleration of oxygen during dipolarizations in lines 51-53 and the whole text is about O+.

5. lines 90-91, "At present, O+ near the dayside low-latitude magnetopause during substorm expansion phase and recovery phase are still not understood" –> What exactly do you mean under not understood? Which scientific questions are still open? Which questions do you try to answer?

6. lines 91-93, there is paper by Luo et al., JGR, 2017, 10.1002/2016JA023471, in which the energization of O+ at the dayside is discussed. The study also discusses asymmetries of the energetic oxygen due to IMF By and Bz directions. Both IMF By

and Bz influence the oxygen abundance at higher energies. However, this is large statistical study and not only cases for the intense substorms. This can be discussed.

7. lines 125-126, 130-131, 180-181, please provide more precise definition of the substorm onset and recovery phase. For example in paper by Newell and Gjerloev, JGR, 2011, 10.1029/2011JA016779, is a nice example on how to define substorm onset, also using more precise SML index available at the SuperMAG. I do not think that definition when "AE index significantly increases" is a precise one. I do not think that one should provide twice the information about substorm onset in lines 125-126 and 130-131. I would remove the second sentence.

8. lines 179-180, actual observations of the IMF and solar wind dynamic pressure could be used directly from the MMS observations at the magnetopause crossings. This would be much more precise.

9. lines 277-278, For higher energies the larger statistics one can clearly see that the stronger duskward asymmetry in the plasma sheet and the dayside magnetosphere is observed under the southward IMF, e.g. Luo et al., JGR, 2017. One should mention that no influence of IMF Bz is observed in case of the energies below 40 keV and for 31 intense substorm events.

10. lines 286-287, the energetic O+ occurs predominantly under southward IMF. Here I would say that it was chosen to be like this. Choosing the intense substorms one increases the probability of observing the southward IMF quite significantly. This also contradicts to statement in the lines 277-278, that IMF Bz does not influence abundance of O+ at the magnetopause. There is not enough provided data to conclude so. By increasing the number of events under the northward IMF one may see a different picture. One can see pretty nice trend in Figure 6b, that the abundance is increasing with the decrease of IMF Bz at least for the expansion phase. Generally on my opinion there is not enough statistics in this study to make conclusions about IMF dependence. One should expand the statistics.

11. lines 304-306, This conclusion is not supported by the observations. Just looking at the scatter points of the number density, I do not see a statistically significant difference between these two phases. One should either show fits to those points or bin them according to some parameters and show that the difference is significant.

12. lines 313-315, energetic oxygen ions also indicate the transport at the dayside magnetosphere (e.g. Liao et. al, JGR, 2010, 10.1029/2010JA015613). These different transports is hard to distinguish (e.g. Luo et al., JGR, 2017).

13. Figures 4-7, just looking at the scatter plots it is hard to make certain conclusions. One should either bin the points to show average trend or fit them with some dependences and increase the number of events.

Minor comments:

1. line 19, What is the energy range of the oxygen observations used in this study? Please indicate the upper energy limit in the abstract. This is important to know when assessing the number densities.

2. line 45, I did not find the reference to Lui et al., 1999 in the reference list.

3. line 47, "during activity geomagnetic disturbance" –> "during disturbed geomagnetic activity"

4. line 55, "[e.g. Yau and Andre, 1997]. And then..." –> "[e.g. Yau and Andre, 1997]. Then..."

5. line 85, please remove one "However".

6. lines 106-107, Does HPCA distinguish between O+, N+ and C+? Or what measured is actually the CNO group?

7. line 122, "At the beginning of the time interval, the solar wind dynamic pressure..." –> The dynamic pressure is only at the begging of the time interval about 2 nPa.

8. lines 124-125, I would change to " These solar wind conditions led to the intense substorm (AE>500 nT).

9. lines 148-150, Figure 2, I would say that the fluxes at energies below 2 keV in Figure 2j is also contamination. This should be mentioned also in Figure caption and even better when it is indicated on plot itself.

10. line 195, I would remove "On the other hand".

11. lines 221-224, These results also agree with Kronberg et al., JGR, 2012, 10.1029/2012JA018071 which show for 10 keV O+ strong increase under the duskward IMF indicated by the clock angle in the inner magnetosphere.

12. lines 251-268, another reason can be that Bouhram et al., 2005 have used somewhat different energy range for O+ observations.

13. line 276, magenetopause –> magnetopause

14. line 279, have –> has

15. line 287, dominated occurring –> occurs predominantly

18. lines 296-297, I would change this sentence to "The reconnection rate is likely will be reduced by the mass-loading but not suppressed at the magnetopause [Fuselier et al., 2019].

19. Figure 1, caption, "The three components of the IMF, Bx, By, Bz..."

20. Figure 2, I would indicate on the plot contamination. In the caption, line 481 (k)–>(l)

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