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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 #3

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This manuscript provides a statistical analysis of the energetic O+ density, O+ flux, and ratio of O+/H+ observed by MMS at the duskside magnetopause during intense substorms. The paper presents new results which are of interest to the scientific community, however there needs to be greater clarification on much of the statistical methods and conclusions. The results have potential to be published in Annales Geophsicae with consideration and adequate response to the following comments and suggestions.

Comments: Lines 90-95: There is a lot of information leading up to this point in the introduction, however with the lines preceding and in this paragraph itself, it is unclear what is not well understood and how/what this paper will provide to answers to. Cur-

rently, the introduction reads as a quite thorough list of previous studies, but it is not readily apparent how they string together, and what they are necessarily building up to. I would suggest stating what the paper will study before this point and tailoring the introduction to build off of that somewhat, because at this point as a reader it is still unclear.

Lines 128-150: HPCA & FPI fluxes are in differential flux and energy flux units. Is there a benefit in having their fluxes in different units? If they are to remain, a point should be included in the text that the units are different.

Lines 128-150: The HPCA flux in panels i-l have artificial striping every 4 energy bins due to way HPCA determines the count rate over 4 energy channels in survey mode. It would be best to correct this, however, describing the artificial striping would also be sufficient. I am also not certain that these HPCA fluxes are actually omni-directional as they do not appear to be half-spin averaged, please verify.

Lines 134-137: Please describe where the FPI/HPCA moments shown come from. This is quite important since the majority of the results presented are dependent on these moments.

Figures 1-2: I would suggest using these two figures to establish the criteria for the statistical study. In my opinion, more text should be added that describes a greater context for these 2 figures inclusion. Either establishing points that lend themselves to the paper's conclusion and/or use the figure to establish conditions for the statistical study.

Lines 176-181: This is one of the more major comments on the paper. The current description of the event selection criteria is not sufficient. Interpretation of a statistical study is almost entirely dependent on understanding how the statistical study is conducted. It is currently not clear what the criteria for event selection is. Is it any MP crossing with AE > 500? Why was 500 chosen as a threshold in AE (i.e. stats are somewhat low, would AE > 300 or 400 provide more events and still be "intense"?)

How exactly is the magnetopause boundary layer determined? Is there any consideration for if the substorm is during a storm or the 1st/2nd/3rd in a series of substorms? Specifically, how are substorm phases determined? What is meant by the mean value of the flux (over a range of energies, one energy)? How long were the average events? Please provide greater context for the choices of criteria used in this study.

Lines 179-180: One of the main points from this paper is that the high-density O+ can be transported from the nightside tail to the magnetopause where it is observed. Please discuss any effect (or lack thereof) of using OMNI solar wind values at the bow shock to correlate with observations of high O+ density which is being driven by processes which invariably take some amount of time to occur.

Lines 203-205: With the decimation of HPCA fluxes during survey mode, the count rate is recorded/distributed over 3-4 energy channels. With this in mind, is it appropriate to describe the comparisons of the flux as being over such a small energy range, since the flux/count rate could have been dominated by a nearby energy channel? Potentially, it would be more accurate to re-bin the HPCA flux into 16 energy channels instead of 63, and compare the >1 keV flux levels of these larger energy bins. Please discuss, currently it seems a bit misleading to describe the flux as being over such a narrow energy range.

Lines 231-236: Here it is stated that, "the maximum number density of energetic O+ at the dusk flank magnetopause is during the intense substorms recovery phase under the southward IMF. But the maximum ratio of n(O+)/n(H+) at the dusk flank magnetopause is during intense substorm recovery phase under the northward IMF. IMF Bz seems play a minor role in O+ 235 abundance at the dusk flank magnetopause during intense substorm." It is not clear from the data as it is presented that this is true. The density ratio is of course dependent on O+ and H+ (which can come from the ionosphere and the sw). Comparing Figures 4a and 5a, it is not clear to me by eye that n(O+) is more dependent on By than Bz. It very well may be, but it is not readily apparent. Thus, is the density ratio difference actually from O+ or H+? Additionally, only 6 of

the events in the study have a Bz > 0. This is notable, as Bz not being random does have an impact on the events. Thus, from this study it appears that Bz does play a role in the events being studied.

Lines 241-242: "number density ratio at the dusk flank magnetopause during intense substorms have a weak correlation with the solar wind dynamic pressure." Can you quantify this correlation? In general, there are a lot of points currently that are driven from visual inspection of very scattered plots, when greater statistical rigor perhaps could be applied.

Figures 4-7: The captions of the figures mention that the 95% confidence intervals are shown. Please mention this in the text and describe how it is calculated.

Very minor comments: Lines 103-106: Please explicitly state that FPI does not discriminate between different ion species.

Line 107: Strictly speaking, HPCA measures up to ∼40 keV/q (thus for He++ this gets up towards 80 keV).

Line 116: The authors might as well finish this thought, that this is due to spacecraft separation/scales of particle motion.

Line 296: Fuselise et al. should be Fuselier.

Lines 304-306: I would re-phrase this sentence. It is a minor distinction, but it currently reads as if you have studied energetic O+ across the entire magnetopause during substroms and found that the most prevalent region of O+ is the dusk flank during the recovery phase. Whereas, it should be more like, "Observations of energetic O+ at the dusk flank magnetopause during substorms are mainly found within the recovery phase."