

Author Response to RC1

July 31, 2022

Major comments:

1. *One of the major concerns is that the purpose/motivation and new aspects of this paper are unclear. The manuscript does not explain why they examined the morphology PMAFs and why they could examine the morphology “in detail” (e.g., due to new data/method). The term “in detail” is very ambiguous, and the critical point is what those details are. As the authors say in the abstract, previous studies have examined PMAF morphology. The authors should focus more on what is different data/methods and new finding compared with those previous studies.*

Thank you for bringing this up. The motivation behind this paper is that there has not been a study dedicated to the morphological evolution of PMAFs. There have only been previous studies with different focuses that commented on the morphology of PMAFs, however no detailed (as in, in-depth) study of the subject. We have listed the exact advances and novel aspects this paper introduces in response to your first specific comment. We will rework the introduction section to include the information provided in that response.

Furthermore, it is not necessarily the methods and data that are inherently different from previous studies, with the exception of our analysis of the arciness index in relation to PMAF occurrence, but rather the depth of analysis.

2. *The title “Morphology of Poleward Moving Auroral Forms” is too general, and such a title is suitable for a review paper or the first report on morphology. They argued that they found a new feature, merging auroral patches/arcs into larger-scale PMAFs. If it is a really new finding, this paper should focus on it, and the title should be, for example, “Merging of auroral patches/arcs into large-scale PMAFs”. More analysis and discussion of the generation mechanism of this phenomenon are needed. Also, I wonder whether this feature is a new typical feature or a particular case of PMAFs?*

Thank you for your comment and suggestion of a new title. We chose this title since this paper is the first paper dedicated to the morphology of PMAFs. And you are right, this topic has been commented on multiple times in previous studies. However, each of those studies were not focused on PMAF morphology.

Moreover, while a major new finding of our paper is the discovery of auroral patches merging before the start of a PMAF event, this is not the only new finding, as there are other important aspects we discuss. Additionally, the arciness analysis is also an important part of our paper which validates our description of PMAF morphology. Thus, it does not seem appropriate to call our paper “Merging of auroral patches into large-scale PMAFs”, as that title does not fully describe the breadth of our paper, since it introduces many new points beyond the merging of auroral patches into PMAFs. However, we are surely open to changing the title, provided the new title encompasses all parts of our study. We suggest ‘Morphological evolution and spatial profile changes of poleward moving auroral forms’.

We observed the merging of auroral patches into a large-scale arc in less than half of PMAFs in this study. We will make sure this is clearly mentioned in the manuscript.

3. *The analysis of the arciness index is not needed for this paper since it looks like a different topic.*

Also, it did not help find a new morphology of PMAFs.

We believe the arciness analysis is a valuable part of this paper. Arciness has been used multiple times in the literature [Partamies et al., 2022, Partamies et al., 2014, Partamies et al., 2017b, Partamies et al., 2017a, Partamies et al., 2015] and has been established as a useful tool to quantify auroral morphology. The major advantage arciness brings to the table is that it is a completely objective measure of auroral morphology. Beyond that, due its quantitative nature, arciness allows us to investigate the morphology of PMAFs in a statistical manner using superposed epoch analyses. Since we are able to explain the evolution of arciness based on our description of PMAF morphology, this validates our report on PMAF morphology.

Specific comments:

P5 section 4.1: The authors abruptly summarize the general morphological evolution without showing any data supporting it. Multiple examples, at least 3-4 cases, showing the general morphological evolution should be displayed before the summary. Also, what is new points that previous works have not been reported?

We are happy to rearrange section 4.1 to show our summary of the morphological evolution of PMAFs after showing fig. 2 and fig. 3, which combined give three examples of PMAF morphology. Furthermore, fig. 6 gives a fourth example of the morphological evolution of PMAFs. Thus, we believe there are enough specific examples in our manuscript to support our description.

The novel points this paper introduces are numerous small advances and one or two more significant conclusions rather than a single major finding. These new findings are further verified by the use of the arciness analysis, the results of which can be understood based on our description of PMAF morphology.

This paper contributes to the literature by reporting novel aspects on PMAF morphology. One of the novel aspects we report is the observation that PMAFs can form following the merging of distinct auroral patches into a singular arc-like structure, the PMAF. In the literature, the beginning of a PMAF is typically described as an appearance of an auroral arc or a the intensification of the equatorward boundary of the dayside auroral oval. We propose a possible explanation for this phenomenon, which relates to the occurrence of localized dayside magnetopause reconnection, or the localized differences in reconnection efficiencies.

Another new point we report is the intensification of the auroral oval happening at the open-closed boundary, as opposed to the equatorward boundary of the auroral oval. While this difference might seem semantic in nature, because those two domains overlap around magnetic noon, they are not identical. Further away from noon (9-10 and 14-15 MLT), the open closed boundary is inside the dayside auroral oval and PMAFs at those magnetic local times do not emerge from the equatorward boundary of the dayside auroral oval. The equatorward boundary of the auroral oval between dusk/dawn and magnetic noon is on closed field lines, as there can be auroral precipitation from the plasma sheet. The open-closed boundary is poleward of the equatorward boundary and it determines the location at which PMAFs first appear, as they exist exclusively on open field lines.

Furthermore, we also observed PMAFs to frequently expand along the north-south dimension as they propagate poleward, specifically near the end of their lifetime. This has also never been reported before.

We compare some of our conclusions to the conclusion made by Sandholt and Farrugia (2007). They reported a strong dependency in the occurrence of PMAF categories 1 and 2 on IMF B_y and magnetic local time, where under positive IMF B_y PMAF2s would almost exclusively occur in the pre-noon sector, while under the same IMF conditions observations of PMAF1s would strongly outnumber those of PMAF2s in the post-noon sector. We have found no such relationship. In our data, we observe approximately 70% PMAF2s and 30% PMAF1s, with no apparent preference for pre-noon or post-noon occurrence under any IMF conditions.

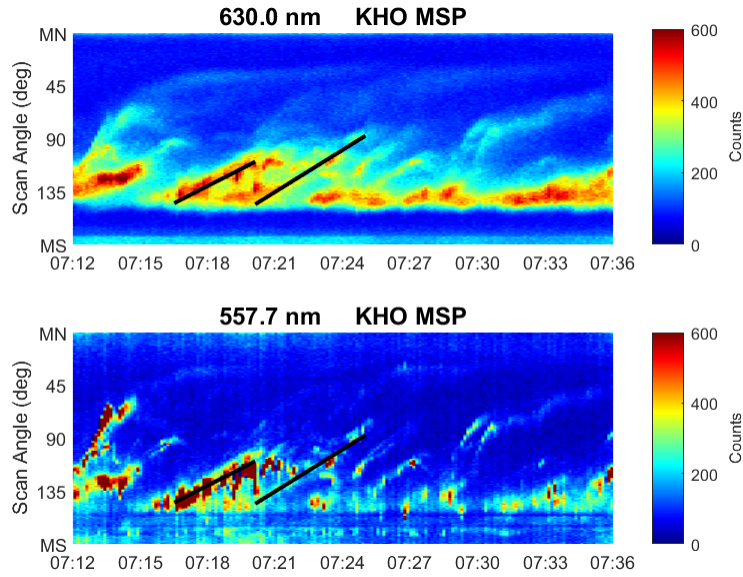
Sandholt and Farrugia also reported observations of poleward boundary intensifications, as opposed to

equatorward boundary intensifications, for PMAFs occurring in the post-noon sector under IMF $B_y > 0$ and in the pre-noon sector under IMF $B_y < 0$. While we did not observe intensifications of the auroral oval at its poleward boundary, we did frequently observe intensifications inside the auroral oval and hence poleward of the equatorward boundary. This relates to our previous finding of PMAFs emerging from the open-closed boundary, rather than the equatorward boundary of the auroral oval.

They were also the first to report that PMAF2 events would have a higher green auroral emission component after the rebrighthening event close to the end of the PMAF lifetime. We can confirm this finding based on our data and interpret it according to the proposed re-brightening mechanism proposed by [Fasel et al., 1992].

Fig3: I cannot see the arc moved poleward. Is this really PMAF event? The author should quantify the velocity of the move of aurora. Also, latitude-longitude grids are needed to identify right direction.

Thank you for pointing this out. The poleward motion is in fact hard to make out from the ASC image series. This is partly due to the fact that the westward motion is dominant over the poleward propagation. Here is a keogram that includes the event time frame. The black lines show approximate locations of two PMAF events that are visible in the ASC image series in fig. 2. We can include the keogram in our manuscript.



p9 L2: Where are data supporting “no relationship between PMAF occurrence time and class.”?

Thank you for this question. We have not included any raw data on PMAF class for each event in the manuscript. As an example, here are the PMAFs of event list 2 sorted by PMAF class and start time (times are in UT, $MLT \approx UT + 3$):

PMAF1: (06:31, 06:56, 07:11, 07:25, 07:51, 08:12, 08:19, 08:52, 09:25, 09:29)

PMAF2: (06:16, 06:25, 06:50, 07:16, 07:35, 07:46, 07:56, 08:00, 08:39, 09:06, 09:17, 09:35)

Evidently, there is no preference for either class in the pre-/post-noon sector in our data, as has been reported by [Sandholt and Farrugia, 2007]. We will gladly include this data in our manuscript.

Fig6: Why the author uses several events not all the events?

Thank you for catching this. These plots were made with all events. However, you are right that the use of the word 'several' is confusing here, and has been changed to 'all'.

Fig7: Why values of arcness are not shown in the figure? P12 L14: Where are data supporting "the general evolution of arciness relating to PMAF occurrence."?

That paragraph refers to the general evolution of arciness over the course of PMAF events, and how that evolution relates to the general evolution of the morphology of PMAFs. We use fig. 7 as an example to map actual ASC images to approximate times in the arciness evolution (fig. 6) and to give another example of PMAF morphology. Hence, the data is contained in fig. 6. We do not show arciness values for the ASC images in fig. 7 as it is merely an example, and cannot be used to validate the results of a statistical analysis, the results of which are plotted in fig. 6.

References

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