Ann. Geophys. Discuss.,
https://doi.org/10.5194/angeo-2018-45-AC1, 2018

Annales Geophysicae Discussions

Interactive comment on "A source mechanism for magnetotail current sheet flapping" *by* Liisa Juusola et al.

Liisa Juusola et al.

liisa.juusola@fmi.fi

Received and published: 26 June 2018

>Anonymous Referee #1

>Received and published: 18 June 2018

>Using the two dimensional global hybrid-Vlasov model Vlasiator, Juusola et al studied the characteristics and source of current sheet flapping in the center of the magnetotail. Their simulations show that an initial down-tail propagating current sheet displacement caused by a hemispherically asymmetric magnetopause perturbation can launch a standing magnetosonic wave within the magnetotail, which acts as a resonance cavity, creating subsequent flapping waves in the current sheet. In three dimensional, Juusola et al suggest that such source mechanism for current sheet flapping could create

Printer-friendly version

Discussion paper

kink-like waves that had been observed to emit from the center of the tail towards the dawn-dusk flanks. The simulation results from this study could potentially provide explanation on the mechanism for current sheet flapping, which till this day remains unknown, and increase our understanding of the tail flapping phenomenon. However, much clarification is needed as terminologies are not clearly defined and loosely used. Analysis of results to support their conclusion are lacking, vague and qualitative. In my opinion, major revisions to the manuscript and further clarifications are required.

We thank the Referee for their constructive comments. We are happy to make many of the suggested changes. In some cases we suggest alternative approaches, in order to avoid making the manuscript too long to be concise and readable. Please see below for our point-by-point replies.

>Comments: 1. Page 1 Line 19: Shouldn't it be "up and down relative to the spacecraft", instead of "back and forth across the spacecraft"? Please clarify.

Yes, we are happy to make the suggested correction.

>2. Page 2 Line 9: Insert appropriate reference Sun et al., [2013] THEMIS Observation of a magnetotail current sheet flapping.

We can add the reference.

>3. Page 2 Line 9: In this sentence, the authors categorized current sheet flapping events into three types (Steady, kink-like along y and kink-like along x). To my understanding of this study, Juusola et al focused primarily on the "kink-type along x" current sheet flapping. However, subsequently in the text, the authors used the word current sheet flapping to describe tailward propagating displacement of the current sheet, which I take it to mean "kink-type along x". However, the term current sheet flapping is more commonly described as steady or kink-like along the y-direction in current literature. The authors should clearly state or define what kind of current sheet flapping they are referring to throughout the text so as to not confuse the readers. If at all possible,

Printer-friendly version

Discussion paper

I would suggest the authors to avoid using tail flapping in this study since many current sheet flapping studies using THEMIS and Cluster data concluded that the current sheet flapping waves travel towards the dawn or dusk flanks (e.g. See review paper by M. Volwerk), which to my understanding from the text, is not what the authors are referring to. This will avoid confusing the readers.

As explained in the first paragraph of the Introduction (page 1, lines 17-21), the term current sheet flapping has originally been used to refer to up and down motion of the current sheet that can be observed as variations in Bx. We show that our simulated signatures produce the appropriate Bx time series, and thus using the term "current sheet flapping" should be justified.

In later studies, different types of flapping (all of which can produce similar time series of Bx) have been distinguished (page 2, lines 3-10). These include the kink-like flapping in the y direction. Because this kind of flapping has been so widely studied, as also pointed out by the Referee, we wanted to make it clear to the reader that our analysis does not directly apply to it, although the results could be relevant to it as well (page 2, lines 27-29).

In order to clarify the issue, we suggest to modify the text on page 2, lines 27-29 to: "Because the simulation is 2D, we concentrate on the characteristics and source of the waves in the center of the tail (i.e., waves in the x-z plane). We also discuss the possibility that in 3D, they could drive the kink-like waves that are emitted from the center of the tail and propagate dawnward and duskward (i.e., waves in the y-z plane)."

>4. Page 3 Line 13: The authors should justify their choice of solar wind parameters in their simulation. A particular set of solar wind conditions, instead of a range of values, are used in this study. This begs the question of how does the solar wind conditions affect the simulation results and conclusion of this study.

A particular set of solar wind conditions instead of a range of values was used because of the heavy computational load of running this type of a simulation. This same run has been analyzed in several previous studies as well (page 2, lines 23-25). The run was suitable for our study, because current sheet flapping occurred in it. How solar wind conditions affect the results is a very interesting question indeed. However, it is outside the scope of this study.

>5. Page 3 Line 23: I strongly suggest that the authors start section 3 with the simulation results shown in Figure 7. By replacing Figure 1 with Figure 7, it will provide context for readers who are either not used to or not familiar with simulation studies and improve the flow of the manuscript.

We are happy to make the suggested change.

>6. Page 5 Line 10: One of the main conclusions of this simulation study was that the "asymmetric perturbation consists of a simultaneous compression of the northern tail lobe and expansion of the southern tail lobe" drives current sheet flapping as shown in their simulation results. However, it is unclear whether this asymmetric perturbation in the simulation is physical or numerical. Furthermore, the authors mentioned that this asymmetric perturbation is caused by subsolar magnetic reconnection (line 8), which is counter-intuitive. Under steady solar wind conditions and dayside reconnection occurring at the subsolar magnetopause region, shouldn't the loading of the open flux in the two hemisphere of the tail be equal? One might think that unequal loading of open flux in the northern and southern tail lobe is caused by dayside reconnection occurring at higher latitude. Would this implies that the perturbation is a numerical effect? Furthermore, Figure 3 shows that there are regions of high beta around the nightside magnetopause surface. Are there turbulence occurring on the magnetopause surface? Could that been the cause of the asymmetric perturbation? Please clarify.

Loading of open flux in the two hemispheres should indeed be equal under steady southward solar wind conditions. However, the loading process can still create hemispherically asymmetric perturbations. As shown by Hoilijoki et al. (2017) and Jarvinen et al., (2018), the perturbations created by subsolar reconnection (magnetic islands, exhaust jets, waves) in the simulation are hemispherically asymmetrical at any given moment of time. The instabilities are seeded by noise at the numerical level, which is not symmetrical. Furthermore, as pointed out by the Referee, turbulence can create and strengthen the asymmetric perturbation as well. Thus, the hemispherically asymmetric magnetopause perturbation that we interpret to initiate the flapping can, according to our understanding, be interpreted to be of physical origin. Because we do not believe that the exact creation mechanism of the perturbation is relevant to the results (page 7, lines 17-24), we have omitted any further analysis of its creation from the text.

>7. Page 6 Line 9: The use of "cross-tail direction", which traditionally referred to the y-direction, is very confusing. The simulation is two dimensional in the x and z-direction. Unless the authors meant cross-tail in the z-direction? If that's the case, the authors should be clear on that as ambiguous use of words could mislead the readers.

We are happy to replace "cross-tail" with "x-z".

>8. Page 7 Line 1: In the discussion section, Juusola et al suggested that in three dimensions, the asymmetric perturbation could have a finite extent in the y-direction, thus driving current sheet flapping in the dawn-dusk direction. However, the authors neither substantiate their conclusion with any 3D simulations results nor conduct any experiments that investigate the effects of a finite IMF By on the occurrence and properties of tail flapping waves. Since the authors listed this as one of the five main conclusion of this study, I think substantial work should be done to demonstrate the connection between asymmetric perturbation mechanism and current sheet flapping in the dawn-dusk direction as observed by earlier studies, rather than simply providing a hand-wavy, qualitative explanation.

We agree with the Referee that listing such claims as conclusions would require further analysis, and we suggest to remove the last point from the list of conclusions in section 5. However, we find these to be valid discussion points, the examination of which could lead to further studies. Thus, we would still like to mention the possibility that the flapping created through our suggested mechanism could act as a source for the waves that propagate in the y direction both in the abstract and in section 5 (as a separate paragraph below the list of conclusions). However, we would further emphasize that this is only a suggestion and would require further study. For example: “The suggested mechanism could act as a source for kink-like waves that are emitted from the center of the tail and propagate toward the dawn and dusk flanks. However, further research using a 3D simulation will be needed to examine this suggestion.” Page 1, lines 12-13 could be modified to: “It may be possible that the suggested mechanism could act as a source for kink-like waves that have been observed to be emitted from the center of the tail and to propagate toward the dawn and dusk flanks.”

>9. Page 7 Line 25: Juusola et al stated model predictions for the purpose of future validations with satellite observations. However, the authors did not follow up on this idea of validations with observations, which I think is a wonderful idea. If it is the authors’ intention to validate their simulation results with observations, this study should provide more quantitative results (e.g. what is the relationship between flapping period and lobe pressure? Does it follows a power law or linear relation etc?) and measurable quantities. These information could be easily obtained from the simulation.

We agree that it may be desirable to derive more quantitative predictions for the purpose of further validations with observations. However, providing numbers for the validation is not straightforward, because they are likely to depend not only on the driving solar wind conditions but the history of the magnetospheric dynamics. A simple confirmation that the period of the flapping signatures decreases as the lobe pressure increases would be a good starting point, and numbers could be provided when running several 3D simulations representing a range of solar wind conditions becomes possible, which would probably require a full dedicated study.

Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2018-45,

2018.