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Interactive comment on "Statistical survey of day-side magnetospheric current flow using Cluster observations: Bow shock" *by* Evelyn Liebert et al.

Evelyn Liebert et al.

e.liebert@tu-bs.de

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We want to thank the referee for this helpful and constructive criticism.

General comments:

Figure captions: Thanks for pointing out that several figure descriptions should be optimized for a better understanding of the pictures themselves as well as the results of our study. We will improve the figure captions and add more descriptions in the text.

Language issues: We will correct them in the revision.

Special comments:

1) Locations of events: We will add a picture presenting the locations of the investigated Cluster bow shock crossings in GSM-coordinates.

2) IMF-aligned Coordinate-System, rotation around x-axis: Thanks for pointing out that the description of the motivation for this transformation as well as the formulations in the text should be improved. The current directions at the bow shock are directly controlled by the IMF orientation via Amperè's law. As we do not confine our study to mainly north-south orientated IMF, the presentation of the resulting current directions in a GSE or GSM-system like in Fig. 4 but without the rotation around the x-axis leads to a quite chaotic looking distribution of the current arrows making it impossible to extract any useful information from it as indeed the required information of the IMF would not be included in such a picture. In contrast, by using the rotated system, aligned to the IMF-x-z-componten for each event, the collective orientation of the currents becomes visible as presented in Fig. 4. Also the differences between the quasi-parallel and the quasi-perpendicular bow shock currents are plain to see after the transformation. In our revision we will correct the existing inconsistency of the formulations regarding the use of our reference system and add additional words about the motivation and advantage of using it.

3) Based on Ampère's law and the Rankine-Hugoniot conditions one can expect a linear correlation between the current magnitude and the mangetic field strength of the IMF tangential component with respect to the shock surface: J $\sim$ [B_t] $\sim$ B_IMF,t. To make this clearer in figure 6 we will add a linear fit to the data points (see attached figure 1). The correlation coefficient is 0.84.

In the limit of high Mach number one can derive J = 3 B_IMF,t/(μ0 L) where L is the bow shock thickness. The slope of the linear fit provides an estimate of the average bow shock thickness of about 1600 km. As the current magnitudes are influenced by the averaging in time and space (averaging window, spacecraft separation, average current density along event trajectory), it is more likely that the current magnitudes tend to be underestimated than overestimated. A direct comparison of some events wich were analyzed in the study by Tang et al. 2012 as well as in our study show that the current density magnitudes calculated with the curlometer technique are by a factor between 2.7 and 4.5 smaller than those calculated by determination of the layer thickness and the jump in the magnetic field. The value of 1600 km therefore represents an upper estimate of the shock thickness. Bale at al. 2003 performed an extensive study of the bow shock thickness which gives a typical scale of a few hundreds of kilometers.

4) We will add a more specific caption to the scheme, also mentioning the spatial scales.

5) Fig. 5 only gives information about the magnitudes. The current directions are discussed in the sections above accompanied by the figures 3 and 4.

Current closure: Thank you very much for your hint at the work of Hamrin et al., 2017, and their approach for investigating the current closure via the current component normal to the bow shock. That is a very interesting idea, and we have now performed a similar investigation of our bow shock currents. To enable a good comparison between the results from Hamrin et al. (their event selection focused on "clear and simple" events) and our events we restrict our analysis to the observed quasi-perpendicular events. Because of the MMS-orbit, the events within the Hamrin et al. study are mainly located within the range of about -7 RE < y < 7 RE (GSM). Transferred to the system of reference we use in our study this corresponds approximately to -0.5 D_BS < y < 0.5 D_BS, where D_BS is the bow shock standoff distance (compare fig. 4).

As the events from the Hamrin et al. study are located near the bow shock nose they introduce the approximation Jn = Jx. They find that the Jn (=Jx) components point outwards at y < 0 and inwards at y > 0 for northward IMF. This is consistent to the current direction parallel to the bow shock in the picture of possible current closure. For southward IMF all current directions are reversed.

Our picture 4 shows the Jx component of the Cluster events within the top panel (x-y-plane). Additionally, the Jx direction is presented by the color code used in the top

and the middle (y-z-plane) panel. Green colors depict Jx directions that are pointing outwards and red colors depict Jx directions that are pointing inwards. At y < 0 the geen color is dominating, while red dominates at y > 0. As the events are presented in our reference system (GSM rotated around x-axis), the picture includes northward, southward, and intermediate IMF orientations all together.

The distribution of the colors in fig. 4 shows that the results for the orientation of the Jx component from the Hamrin study and from our study are qualitatively identical. A significant difference is the spacial distribution of the events. The MMS events provide a very good coverage near the bow shock nose, while the Cluster events are distributed over wider distances from the bow shock nose. In our study, we interpreted the spatial distribution of the Jx component as a resemblence of the large scale bow shock curvature. In fig. 4, x-y-plane, one can see that the currents follow the shape of the model bow shock quite well.

The approximation Jn = Jx could include a significant error when applied to the Cluster events from our study because of the distance from the shock nose. In our additional investigation we therefore calculate Jn via the local bow shock normal: Jn = J * n We analyzed the orientation of Jn in dependence of the y-coordinate (within the reference system) for our quasi-perpendicular shock events. The table shown it attached figure 2 gives the occurance rate of outward and inward orientation for -0.5 D_BS < y < 0 and 0 < y < 0.5 D_BS (which is about the coverage of the MMS events from the Hamrin et al. study) as well as for y < -0.5 D_BS and 0.5 D_BS < y (additional locations because of the Cluster orbit)

Based on these numbers we can not identify a general majority of outwart pointing Jn at y < 0 and inward pointing Jn at y > 0 which would be expected from the picture of Jn resembling the current closure via the magnetosheath.

6) Results from Harmin et al., 2017: We will include references to as well as comparisons with their results in our revision.

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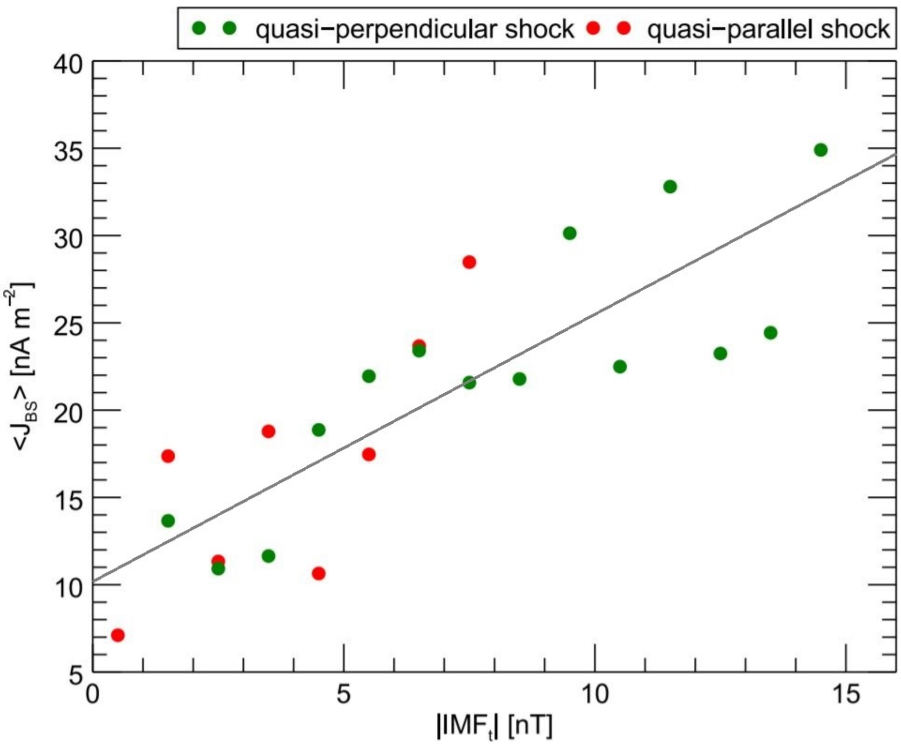

Fig. 1.

Occurance rate of outward and inward pointing directions of the current normal component at the quasi-perpendicular shock depending on the y-coordiniate (reference system) in units of the bow shock standoff distance.

	y < -0.5	-0.5 < y < 0	0 < y < 0.5	0.5 < y
Jn pointing outwards	38 (45%)	36 (61%)	37 (57%)	47 (67%)
Jn pointing inwards:	46 (55%)	29 (39%)	28 (43%)	27 (36%)

Fig. 2.