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Interactive comment

Interactive comment on "Roles of electrons and ions in formation of the current in mirror mode structures in the terrestrial plasma sheet: MMS observations" *by* Guoqiang Wang et al.

Anonymous Referee #1

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1 General remarks

The submitted manuscript investigates the electric current distribution within two magnetic dips identified as mirror mode structures in the terrestrial plasma sheet. As these are quasi-stationary magnetic field structures in the plasma frame, they must be supported by electric currents. According to the Authors, the currents are carried preponderantly by either electrons or ions, depending on the scale of the structure. To my knowledge this is the first experimental study of these current systems, therefore the manuscript can add a valuable contribution to our current understanding of the mirror modes. There are however a number of issues which should be addressed before

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publication.

Despite the availability of magnetic field and particle data from the four MMS spacecraft forming a “tetrahedron with inter-spacecraft distances of tens km” – as mentioned in page 2, line 79 of the manuscript, little advantage of the multi-point measurements is taken by the Authors. As far as I can tell, the multi-point capabilities of the MMS fleet were only used to determine the spacecraft-frame velocities of the detected compressional fluctuations (page 5-6, lines 113-120). Everywhere else, only single spacecraft data seems to be used. I am aware that the tetrahedron configuration might not be appropriate for some multi-point techniques, such as the curlometer, or that the characteristic size of the tetrahedron might not be ideal for the scale of the investigated structures. Nevertheless, the Authors should either use the measurements from all spacecraft or clearly explain why some of the data is excluded from the analysis. There is only a brief remark in this direction in the manuscript, stating that the interspacecraft distances are to small to allow an estimation of the magnetic field curvature (page 12, lines 270-272).

Even when essentially single spacecraft data are used (e.g. determining the principal coordinate system, scales of the structures, instability condition, current densities, pressures, particle velocities), reference should be made to all four MMS spacecraft, differences between spacecraft discussed, and when possible mean values used. In particular, figures 2 and 3 should include all spacecraft.

The text should be better structured and the language should be revised throughout the manuscript.

2 Specific comments

- page 2, line 37-39

Due to gradients in the magnetic field and plasma density, the mirror mode waves may slowly propagate relative to the ambient plasma flow (Hasegawa 1969, Pokhotelov JGRA 2003).

• page 5-6, line 115-120

More details about the timing method used to estimate the velocity of the compressional oscillations should be given. What are the time delays, accuracy? Tetrahedron size, elongation and planarity should be discussed. Is the determined speed the phase velocity in the spacecraft frame? (i.e. planar wave fronts orthogonal to the determined velocity vector are assumed? – if yes, then the direction of the determined velocity vector should be compared with the minimum variance direction determined on page 7, line 153. They should agree.). Since the Authors refer to the oscillations between 20:51 and 21:04 (page 5, line 112) why only the interval [20:51:55, 20:53], corresponding to the later identified (page 7, Table 1) MM1 structure, is used? To ease the interpretation and comparison between the determined phase velocity vector and the mean plasma flow velocity, spherical coordinates (magnitude, θ, φ) should be used, and the angle between the two vectors should be given.

(Harvey 1998) does not appear in the manuscript references list. I assume it is Chapter 12 in the ISSI "Analysis Methods for Multi Spacecraft Data" book.

• page 6, line 127-135

The velocity used for estimating the scales (line 129) should be the one determined from timing analysis, not the plasma flow velocity. Since the two are not very different (line 118), this should not change much the results. Most probably the mirror mode structures have different sizes in different directions. For this study, the relevant size is the size in the direction orthogonal to the magnetic field. This size should be determined considering the angle between the mean magnetic field and the velocity vector determined from the timing analysis. Since the minimum variance direction – which should be close to the velocity direction – seems to be orthogonal to the mean magnetic field (figures 2 and 3), I expect that the sizes estimated in the manuscript are not far from the sizes in the orthogonal to the mean field direction. However, if the structures are not crossed through their centers – e.g. a path similar to the one shown in Figure 5 –, then the estimated sizes are only lower limits.

On lines 131-132 I assume the Authors meant "average ion perpendicular temperature".

• page 7, Table 1

"ρ_i" should read "Scale (ρ_i)".

• page 7, lines 147-159

After line 147 the manuscript concentrates only on two magnetic dips (MM1 and MM5). To help readability, this should be clearly stated. The first structure (MM1) is analysed in this paragraph and in the next one (up to line 181), while MM5 is analysed in the remaining of the section. Dividing the text in subsections would improve readability.

In this context, the maximum variance direction – which for magnetic mirrors should be aligned with the mean magnetic field – is the important direction. Therefore the ratio between the maximum and the intermediate eigenvalues is relevant. The angles between the mean magnetic field and the determined $\mathbf{L}, \mathbf{M}$ and $\mathbf{N}$ directions should be given.

The current density should be computed also using the curlometer, or the Authors should explain why this technique cannot be applied.

Same comments apply for the MM5 on the next page.

• Figures 2 and 3

Figures 2 and 3 should show the orthogonal pressures of both ions and electrons. Are the ion velocities and the electron pressure in Figure 2 smoothed?

• page 7-8, lines 161-174

A more quantitative approach to determine which species (ions or electrons) contribute mostly to the electrical current is desirable. The Authors might e.g. compute the correlation between the electrical current and the ion and electron velocities.

• page 11, lines 240-242

Please state the assumptions made for estimating the current density j_B.

• page 11, lines 251-255

There is no reference to chaotic particles in (Constantinescu 2002). Perhaps the Authors refer to another paper?

• page 12-13, lines 285-295

An estimation of the gradient drift velocities for electrons and ions (similar with the estimation done in the previous paragraph for MM1), as well as an estimation of the electron diamagnetic drift should be given.

• page 13, lines 301-309

The normal directions (line 305) are almost orthogonal to each other. Knowing the estimated size between the entry and exit points, d, one can derive the transversal size of the structure as illustrated in Figure 5 (about $1.4d$). Why is the MMS trajectory a curved line? Does the assumed relative motion of the magnetic structure change so much during the crossing time?

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