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 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).

Answer: Thanks for your nice suggestion. We have added this sentence in our revised manuscript.

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.

Answer: Thanks for your nice comments and suggestions. Burst magnetic field data (a resolution of 128 Hz) are available only between 20:51 and 20:54 UT, thus, we calculate the propagating velocity of the hole-like structure between 20:51:55 and

20:52:56 UT based on timing analysis (Harvey, 1998) to verify whether these compressional structures are non-propagation. Figure 2A shows the positions of the MMS spacecraft relative to MMS1 at 20:52 UT. The inter-spacecraft distances are ~13 to 21 km. Before performing the timing, the magnetic field data have been low-pass filtered with a cutoff period of 30 s to reduce the effect of high frequency fluctuations. Figure 2B shows the cross correlations between MMS1 and the three other satellites by using B_Z. The maximum correlation coefficients are all almost 1 between MMS1 and MMS2/3/4 with a lag time of -0.312 s, -0.164 s and -0.039 s, respectively. The estimated velocity is (71.3, 11.7°, -28°) in spherical coordinates (r, θ, φ) transferred from GSM coordinate system, where θ and φ are the longitude and latitude, respectively. By contrast, the average ion velocity is (71.6, 37.8°, -28.4°) in this interval. Comparing these two velocities, one can find that the compressional structures in Figure 1 are approximately stationary, i.e. they are mirror mode structures. The determined velocity is the phase velocity in the spacecraft frame, i.e. the front of the structure is supposed to be perpendicular to the determined velocity.

The minimum variance direction is supposed to be parallel to the above estimated velocity by timing, however, the angle between these two directions is ~37°. The MVA technique can be effected by waves or noises superimposed on the discontinuity surface, while the inter-spacecraft distances and configuration of the MMS satellites can effect on the accuracy of calculation, which might a possible explanation for the large difference between the two estimated normal directions.

We have added the above details in our revised manuscript.

(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.

Answer: Thanks for your nice comment. Yes, it is this reference. We have added the reference in our revised manuscript.

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.

Answer: Thanks for your nice comment. Of course, it is better to use the velocity determined by timing to estimate the length scale of the mirror mode structure. The inter-spacecraft distances are ~13 to 21 km, which is too small to use the survey magnetic field data to do timing analysis. Only the burst magnetic field data during the first mirror mode structure are available, thus, we just do timing analysis for the first mirror mode structure to verify whether these structures are stationary in the ambient flow. Due to lack of sufficient burst magnetic field data, we estimate the length scale of the mirror mode structure in its cross-section using the M and N components of the ion velocity in our revised manuscript. It is difficult to verify whether the spacecraft trajectory crosses the center of the structure. Therefore, the estimated length is just the lower limits. We have added these details in our revised manuscript.

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

Answer: Thanks for your comment. Yes, we meant “average ion perpendicular temperature”. We have made a correction in our revised manuscript.

Page 7, Table 1

"ρ_i" should read "Scale (ρ_i)".

Answer: Thanks for your nice suggestion. In our paper, we mainly focus on the first and last mirror mode structures. And the information of these two structures have been written in the text. So, the table 1 is found to be not necessary to show, and has been deleted in our revised manuscript.

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 analyzed in this paragraph and in the next one (up to line 181), while MM5 is analyzed 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 **L**; **M** and **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.

Answer: Thanks for your nice comments and suggestions. We have separately analyzed these two mirror mode structures based on your suggestions. The angles between the mean magnetic field and the L, M and N directions are also given in the text. To study the relation between ions/electrons and the current density, the current density calculated by the curlometer method is a better choice. We determined the current density by the curlometer method, and did correlation analysis between the ion/electron velocity and the current density in our revised manuscript.

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?

Answer: Thanks for your suggestions. We have shown the orthogonal pressures of both ions and electrons in these two figures. Only the electron data in these two figures have been smoothed within a 30-second window, since only electron data have significant high-frequency noise.

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.

Answer: Thanks for your nice suggestions. We have calculated the correlation coefficient between the electrical current and the ion/electron velocity in our revised manuscript. "The correlation coefficient between j_N and V_{eN} inside MM1 is -0.97." "The correlation coefficient between V_{iN} and j_N is 0.92 in the whole interval of MM2"

Page 11, lines 240-242

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

Answer: Thanks for your nice suggestion. B_L changes ~5 nT in MM1 between 20:52:30 and 20:52:56 UT, and half of the estimated length of MM1 is 2.05×10^3 km in the cross-section. Assuming that B_M and B_N are 0, and B_L changes just along the trajectory of MMS, a current density j_B with a value of ~2 nA/m^2 in the cross-section is necessary to be self-consistent with the magnetic field depression. We stated the assumption in our revised manuscript.

Page 11, lines 251-255

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

Answer: Thanks for your comment. We have corrected the reference, which is Büchner and Zelenyi (1989).

Büchner, J., and Zelenyi, L. M. Regular and chaotic charged particle motion in magnetotail like field reversals. Journal of Geophysical Research, 94, 11,821–11,842. https://doi.org/10.1029/JA094iA09p11821, 1989.

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.

Answer: Thanks for your comments. We use the data in the time interval between 21:02:30 and 21:02:50 UT to estimate the ion thermal pressure and magnetic gradients. Also, the average ion perpendicular and parallel temperatures, average total magnetic field and average curvature radius in this interval are used to estimate the velocities of the ion drift motions. Consequently, the velocities of the ion diamagnetic, magnetic gradient and curvature drift motions are ~17 km/s, 33 km/s and 79 km/s, respectively. By contrast, the velocities of the electron diamagnetic, magnetic gradient and curvature drifts are ~5 km/s, 14 km/s and 36 km/s. Since the ion diamagnetic and magnetic curvature drifts move almost in the same direction in the M-N plane, while the ion magnetic gradient drift moves in the opposite direction. Thus, the collective drift velocity is ~63 km/s, very close to the ion velocity inside MM2 with a speed of 70 km/s. Thus, one can expect that the bipolar V_{iN} in Figure 4 is the collective behaviors of the ion drift motions in MM2.

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 1:4*d*). Why is the MMS trajectory a curved line? Does the assumed relative motion of the magnetic structure change so much during the crossing time?

Answer: Thanks for your comments. “The normal directions are almost orthogonal to each other, the maximum length of MM2 in the cross-section could be 1.4 times the estimated length (6.6 ρ_i) based on the assumption of a circle.” We found that the M component of the ion velocities V_{iM} at two edges of MM2 are different, so the MMS trajectory was drawn as a curved line. Actually, the difference V_{iM} at two edges of MM2 is not significant, so a straight line could be better to show the MMS trajectory. The trajectory has been changed to be a straight line in this figure in our revised manuscript.