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Interactive comment on "Mirror mode physics: Amplitude limit" *by* Rudolf A. Treumann and Wolfgang Baumjohann

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The manuscript investigates the influence of electron pair formation on the evolution of linearly saturated ion mirror mode. The Authors derive the diamagnetic effect of trapped electron pairs which is proposed to drive the growing of the mirror mode amplitude from a low perturbation in the magnetic field, reached when the initial anisotropy is depleted, to the observed levels comparable with the ambient magnetic field magnitude. By providing a theoretical basis for the observed large amplitudes of the mirror mode, the present work represents a significant contribution to space plasma physics.

The mechanism of electron pair formation proposed in the manuscript is based on the attractive potential due to overcompensation of the charge occurring just outside the

Debye sphere of a moving electron in interaction with a parallel propagating ion sound wave. It is shown that in order for a negative potential to develop, the parallel component of the electron velocity must be close to ion sound wave phase speed. Since the thermal speed of electrons in space plasmas is much larger then the ion sound wave phase speed, this effect is in general of little importance. However, the Authors argue that special conditions encountered inside the quasi linearly saturated magnetic bottles favour the resonance of the trapped electron population with the always present background of ion sound waves. As trapped electrons approach their mirror points, their parallel velocities decrease until the resonance condition is satisfied and a negative potential develops. Another electron moving at almost the same velocity can be captured in the potential well and form a pair.

Minor points

A key assumption throughout the manuscript is the conservation of the magnetic moment of the electrons. However, as the magnetic bubble grows and the field decreases, the gyration radius of the electrons in the low field regions increases. It is known that a necessary condition for the magnetic moment to remain invariant is that the gyration radius of the particle must be much smaller then the curvature radius of the magnetic field. If this condition is not satisfied, the motion of the electron changes from a periodic bounce between the mirror points to an irregular motion. I think this should be mentioned in the paper, or even better an estimate of the fraction (which might be significant) of particles which become irregular and therefore do not participate in the pair forming should be given.

page 4 lines 107 - 114

Electrons with energies larger than $\mathcal{E}_{trap}$ will indeed escape from the bottle *orthogonal* to the magnetic field, however, not all electrons with energies bellow $\mathcal{E}_{trap}$ will be trapped, they might escape of course along the magnetic field if the pitch angle is too small ($|s_m| > \pi/k_\|$). This will affect equation (8) on page 5.

page 18 lines 505-516

The authors should explain the reason for the newly form pair to “drop out” of the bouncing motion and remain locked near the mirror point. The center of mass velocity U must be slightly bellow the ion sound speed for the electron pair to form. If the bouncing motion continues then this condition is quickly broken and the pair disintegrates. If the pair is locked near the mirror point, U vanishes and again the pairing condition is broken. Please clarify how the electron pairs can remain stable, or is rather a dynamic equilibrium at work, where disintegrating pairs are compensated by newly formed ones?

page 18 lines 530-555

It would be useful to discuss how does the diamagnetic effect of the electron pairs compare with the diamagnetic effect of the former “free” electrons before pairing

page 19

Equation (59): after the first “=” sign there should be no “–” sign

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