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Multi-Fluid Model of 1D Magnetotail Current Sheet

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Advances in Simulating and Modeling Magnetospheric Processes Using Data From Multiple Spacecraft III Posters

Abstract #1425

Comparisons of data with models of the magnetotail current sheet have mainly used the Harris model of the current sheet.

The Harris model has important limitations:
1. \( B_z = 0 \), so no particles cross the sheet from asymptotic sources.
2. It assumes a uniform mean y-component of drift velocity.
3. The particle density vanishes asymptotically.

Kinetic and fluid approaches have been used for current sheet models:
1. A fluid model can describe the fluid behavior reasonably well, but needs unknown equations of state for closure.
2. A kinetic model is complicated to construct in that it would have to fit data with expressions involving constants of motion.

A multi-fluid model extends the versatility of the fluid model approach. It can treat sources from opposite sides of the sheet. Boundary conditions can be symmetric or non-symmetric.

Fluid equations are easier to handle than kinetic equations.

Some Previous Magnetotail Current Sheet Work

Speiser, Lyons, Sester, Schindler: Particle trajectories showed acceleration in "non-adiabatic" central region. Gain in speed is primarily in earthward direction. Self-consistent kinetic models used larger scales in x- and y-directions than in z-direction.

Kan: obtained exact 2-D kinetic solutions. His method was followed by others who obtained exact 2-D solutions for X-point structures ( Reviewed by Lui).

Eastwood, Hill, Corfield, et al. discussed fluid and kinetic aspects, showing that balance between \( B \) and \( p_{\perp} \) is important.

Schindler, Sommer: The first adiabatic invariant, \( J \), is conserved through the sheet in spite of failure of the magnetic moment, \( J \) reverses to go at exit from sheet.


Tsyganenko et al: Models of tail \( B \) from spacecraft data. Central gradient in \( B \) due to local current but asymptotic behavior from dipole & remote current-source.

Baumjohann et al: data from traversals of the central sheet show a polystrophic index close to 5/3 and \( T_y \) staying nearly constant at about 7.

Model Assumptions

1. one-dimensional (\( \nu_z = \Delta y = 0 \))
2. steady state (\( \Delta t = 0 \))
3. quasi-neutrality (\( T_e = T_i = 0 \))
4. massless electrons
5. \( E_x = E_y = 0 \) far from current sheet
6. isotermal ion fluid (\( v_i = a_{\perp} T_i \), with \( T_i = \text{constant} \))
7. ion fluids described by a polytropic equation of state (\( \rho_i = \text{constant} \))
8. no trapped ions; however, there are two symmetric, identical, singly charged, ion fluids (\( B_0 = a_{\perp} T_i \), \( u_i = a_{\perp} T_i \), \( T_i = \text{constant} \))

Conclusions: Usefulness of Fluid Current Sheet Models

• The isotropic ion model is an improvement on the Harris model. \( B_z \) is taken into account; it allows passing particles with asymptotic non-zero density and asymptotically vanishing out-of-plane drift speed, \( u_i \).
• They give rise to predictive relationships between the ion pressure, the current sheet thickness, and the density peaking factor.
• Comparison of data with models can be used to help determine the equations of state that may apply under different conditions.
• They are simpler to construct than kinetic models. Also, moments of measured distribution functions (\( \rho, \mu, \eta \)) will provide averages over peculiarities and/or fluctuations in measurements, avoiding some of the difficulties of working with the full velocity distribution function.

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