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# Universal properties of thin current sheets in space plasma

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Thin current sheets (TCSs) with characteristic scales of a spatial inhomogeneity about proton gyroradii are widespread structures in space plasma. Now they are often observed "in situ" within different cosmic systems from various planetary magnetospheres to the entire heliosphere. TCSs are shown to be responsible for the storage of the excess of magnetic energy and its consequent fast release during magnetic reconnection processes that are followed by particle thermalization, wave activity and intense plasma flows along magnetic field lines.

We developed the simple analytical theoretical model of the multiscale TCSs equilibrium where the thinnest current sheet supported by fast curvature drifts of magnetized electrons is embedded inside the thicker proton-dominated sheet where protons go along specific quasiadiabatic serpentine-like trajectories. Our model allows to estimating the self-consistent thickness of the embedded electron surrounded by the proton sheet.

It was shown that the inner electron sheet scaling in TCS should have the universal character for hot collisionless current sheets with absent or small guide field. Newly discovered property of such sheets is the unusual nonlinear profile of magnetic field: $B(z) \sim z^{1/3}$. The corresponding dimensionless asymptotic solutions $b \sim z^{1/3}$ and $b \sim z$ for regions $b(\tilde{z}) \gtrless 1$ are shown by the dashed blue lines in Figure 1 together with the exact numerical solution of the general Ampère equation (red line).

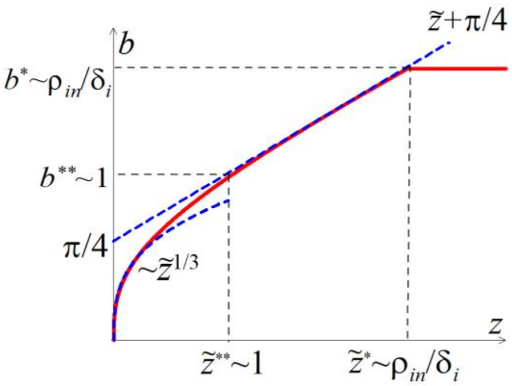


Fig. 1. Characteristic embedded TCS magnetic field $b$ profile as function of dimensionless cross-sheet coordinate $z$ (adapted from the work [1]).

Figure 2 demonstrates the corresponding topology of magnetic field lines $\mathbf{B} = B_x(z)\mathbf{e_x} + B_n\mathbf{e}_z$ . One can clearly see the characteristic "field line tongue" produced in TCS by strong electron drift currents.

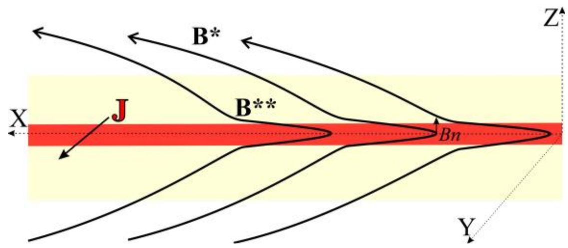


Fig. 2. Topology of magnetic field lines in TCS (adapted from [1]).

Current sheet stability is estimated in a frame of a linear perturbation theory. It is shown that the electron sheet embedding plays a principal role in TCS destruction.

Theory comparison with experimental MMS and MAVEN observations in the terrestrial and Martian magnetotails respectively was made. Magnetic field observations at these spacecraft are capable to resolve extremely fine electron structures usually embedded in a thicker-ion scale current sheets.

Statistics of MAVEN observations of electron current substructures agrees fairly well with theory prediction of (1/3) power index for the magnetic profile[1]. Very compact MMS spacecraft constellation is also favorable for the investigation of electron scale current sheets (CSs). During magnetotail CS crossings in 2017 - 2019 MMS revealed several tens intervals when very intense (~ several tens of nA/m2) and very thin (<100 km) electron CSs were observed. We have analyzed the spatial structure of electron sublayers observed by MMS spacecraft and also found the evidence of nonlinear magnetic field profiles within them. MMS electron observations allowed additionally revealing a number of interesting features demonstrating strong coupling of electron and ion components in TCS configurations.

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References:

[1] L. Zelenyi *et al.*, Geophys. Res. Lett., accepted, doi: 10.1029/2020GL088422, (2020).