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Physics of Boundaries and Their Interactions in Space Plasmas

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I. Large Scale Simulation of the Magnetopause:

We have analyzed our run for southward IMF case in detail. We found a number of interesting features. The flow pattern at the magnetopause is quite complex, and is determined by the combined effect of the convection flow and the flows generated by the reconnection process. There are multiple reconnection sites and the thickness of the magnetopause varies significantly as one moves away from the subsolar point. In most instances, the reconnection site looks quite asymmetric and the fast flow can be generated almost entirely in one direction. Within each reconnection layer, the discontinuities that are formed are highly nonlocal in nature, and differ significantly from the usual discontinuities, such as rotational discontinuities that have been examined in isolation. We are currently writing up our findings for publication in the Geophysical Research Letters.

II. Three-dimensional Simulations

We have analyzed a run with both the tearing mode and the Kelvin-Helmholtz instability. The evolution of the system is as follows. Initially, both KH and tearing mode start to grow. The growth for the tearing mode is almost all in the direction parallel to the background field, whereas the KH grows in the direction perpendicular to the field. This two modal property remains even in the highly nonlinear regime. What happens, however, is that tearing mode generates a core field, which is then amplified significantly by the modulations of the current layer caused by the KH instability. Further, both B_x and B_y grow in both the y and z directions. This is due to the fact that the tearing mode creates a current loop, which in turn becomes unstable to the KH in y as well as z direction. In the pure tearing case, B_x would only grow in the y direction. We are currently writing up the results for publication in the Geophysical Research Letters.

III. Inflow-Outflow Simulations:

Using two-dimensional hybrid simulations of the magnetopause we have been able to show that: (1) nonlocal effects play a major role and affect the properties of the discontinuities associated with the reconnection layer. In particular, in contrast to previous studies, there are no 1-D equivalent of rotational discontinuities or intermediate shocks that are formed. In fact, if one tries to describe the discontinuities in terms of the usual discontinuities, one would be led to conclude that there are slow shocks in the magnetopause. But a more careful analysis, taking into account both the highly nonlocal and two-dimensional nature of the reconnection layer, reveals that the observed discontinuities are simply kinetic structures that have no simple fluid analogues. Further, we were able to demonstrate that the presence of the accelerated flows leads to the Kelvin-Helmholtz instability in the reconnection layer. Finally, in the case of multiple x-lines, we compared the cuts across the plasmoids with the observations of FTEs at the magnetopause. We showed how making different cuts through the plasmoids can lead to different field signatures. We are writing up our results for publication in the Geophysical Research Letters.

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13. ABSTRACT

This report describes the work done by SciberNet, Inc. during the month of January. During this time, we primarily worked on further analysis of the results presented at the AGU as well as writing them up for publication. Using large scale simulations, we showed that the magnetopause during the southward IMF case is quite irregular with varying thickness, and has a complex flow pattern owing to the nonlinear effects of the convective flow superimposed on the flows generated in the reconnection layer. We used inflow-outflow boundary conditions to examine the kinetic nature of the discontinuities that are formed in the reconnection layer and concluded that nonlocal effects play a major role in the formation of such discontinuities and can alter their properties from the usual structures expected from 1-D simulations or from fluid theories. Finally, we used our 3-D simulations to examine the nonlinear interaction of the tearing mode with the Kelvin-Helmholtz instability. We showed that this interaction leads to the generation of a large core field which is observed both in the magnetotail as well as the magnetopause.

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