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MAGNETOTAIL PHYSICS

MAGNETOTAIL PHYSICSAnthony T.Y. Lui (Editor), *The Johns Hopkins University Applied Physics Laboratory*

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Magnetotails are ubiquitous features of planetary magnetospheres. More than 25 years of measurements have demonstrated that the geomagnetic tail is an extremely active region that plays a controlling role in the transport of energy and momentum from the solar wind to the earth's magnetosphere and ionosphere. It is the region where energy is stored (by stretching the magnetic field lines) and subsequently released in extremely short times, driving a phenomenon known as a substorm. In a substorm, energy on the order of 10^{15} J is deposited in the auroral regions and in the magnetosphere within 20 to 30 min, producing many spectacular phenomena such as global auroral displays.

The geomagnetic tail is also the site of many plasma processes, knowledge of which can be applied to space, astrophysical, and laboratory plasmas. Prominent among them is the phenomenon of reconnection of magnetic field lines. It is, therefore, not surprising that an enormous amount of scientific work has been devoted to the geomagnetic tail, which serves as the prototype for other magnetotails and their associated plasma processes.

Until now, the interested researcher had to search through voluminous literature scattered in the scientific journals of many disciplines, with no way of knowing which contributions were outdated, which were controversial, or which were plainly wrong. The problem was particularly acute because magnetotail dynamics has been, over the years, the subject of acrimonious controversies, with various mechanisms advanced as articles of faith, rather than of science, and thereafter supported with religious zeal. The newcomer to the field and the interested graduate student were faced with an impossible sorting task.

The monograph *Magnetotail Physics*, edited by Anthony T. Y. Lui, is a welcome and long-awaited relief. It is based on review papers and contributed papers

presented at the Chapman Conference on Magnetotail Physics held October 28–31, 1985, at The Johns Hopkins University Applied Physics Laboratory. The quality of the monograph's content is, however, much above that of the usual conference proceedings. It is clear that an enormous effort was expended after the conference to produce such a comprehensive and critical review of the subject. The monograph is self-contained and can well serve the beginning graduate student as well as the experienced researcher.

There are eight chapters in the book. Chapter I is composed of a brief tutorial on the magnetosphere domains and nomenclature and a historical perspective of the early years (1960–72) of magnetotail research. The first article is a brief but lucid description by the editor of the relevant physical regions of the magnetosphere that helps the reader organize and classify the rest of the material in a coherent fashion. The second article, by N. Ness, is an inspiring description of how the highly intuitive early "cartoons" of Johnson, Dungey, and Piddington were to come to life with the first set of Explorer spacecraft launched during 1961–68. The controversial cartoons were transformed into reality, and the geomagnetic tail emerged as the most prominent feature. This period also marked the beginning of the next set of critical issues centered on the dynamic behavior of the magnetotail, a major research task that continues today. Taken together, the two articles of the first chapter set the proper tone for the rest of the book.

The next three chapters deal with the main subject of the book, the magnetotail.

Chapter II concentrates on the magnetotail configuration under static equilibrium. It starts with a well-written introduction, by D. Fairfield, of the "average" static structure of the magnetotail, documenting its emergence from the numerous but random spacecraft visits to the region and considerations based on equilibrium pressure balance. This description is followed by a series of articles describing in more detail various observational investigations and their implications for the understanding of equilibrium and transport in terms of static and dynamic models.

Chapter III deals with aspects of the dynamic magnetotail that can be described by considering the magnetoplasma as a fluid. This chapter also starts with a well-balanced review, by the editor, of the observa-

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tional and theoretical status of magnetotail dynamics, with emphasis on substorm-related issues, providing the framework for the other contributions. The chapter includes many new data on substorm-associated plasma flows, magnetic field variations, electrostatic plasma waves, and magnetohydrodynamic (MHD) waves. It also includes contributions supporting the various substorm-triggering "doctrines." While it is obvious that the substorm-triggering process remains an unresolved issue, the various contributions taken together reveal many hints as to what should be discarded and what should be pursued. For example, the article by Coroniti and the remarks by Montgomery can provide the astute reader with insights into the utility of dynamic MHD models, their pitfalls, and the role of classical and anomalous transport in the form of viscosity.

Chapter IV is essentially the last chapter, dealing directly with geomagnetic tail dynamics and focusing on what is both observationally and theoretically the most difficult aspect of the subject—that of kinetic effects. The low level of maturity of the subject is clearly reflected in the unevenness of the presentations and the lack of thematic coherence. The overview, by D. Mitchell, is a good introductory tutorial on the subject of kinetic effects in the tail, although the usefulness of the article would have been greater if the boundary-layer kinetics had been discussed more extensively. This lack is particularly keenly felt, since the subsequent articles, neither individually nor as a group, reflect the crucial role of boundary-layer kinetics. The chapter includes, in the form of a potpourri, good descriptions of the ion distributions in various tail regions, a good example of relevant laboratory simulations with excellent diagnostic presentations, and a glimpse of future attractions in the article on chaotic particle motions. On the other hand, the articles on particle simulation of kinetic tail phenomena represent classic examples of how *not* to do particle simulations of magnetospheric phenomena.

Of the remaining chapters, Chapters V and VI deal with cometary (artificial and real) and planetary tail systems. Chapter V, on the AMPTE experiment, is indicative of a lost opportunity. The most impressive aspect of the chapter is the quality of the experimental data and imagery. Unfortunately, the theoretical discussion and interpretation of the data based on hand-waving arguments are completely unsophisticated and of dubious validity. Chapter VI is a rather superficial description of other planetary and cometary tail interactions; the articles taken by themselves are quite informative, but the overall chapter lacks the unifying glue that characterized Chapters I through IV. The final two chapters (Chapters VII and VIII) return to the subject of Chapters I through IV and provide what, in State Department terminology, would be called a frank exchange of views on the subject. They are a fitting finale to a good conference and a well-prepared monograph. They are indicative of the vitality of the field and of the excitement that characterizes the ongoing research.

In summary, the monograph represents a milestone in magnetotail research. It has been successful in consolidating the understanding of the geotail obtained from the many separate missions and from parallel theoretical analyses and computer simulations. It indicates clearly the road by which the early cartoons were transformed into quantitative models and emphasizes the outstanding questions and future directions. The monograph is also indicative of the maturity of the various topics. For example, the weaknesses of Chapter IV are representative of the immaturity in understanding kinetic effects, rather than poor presentation of the issues by the contributors. Similarly, the deficiencies of Chapter V represent inadequate theoretical support of the AMPTE mission. From beginning to end, the monograph is of high-quality content, is readable, and contains exceptional and highly instructive graphics. It is a first-rate resource on a fascinating area of space plasma physics.