

Foreword

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In September 1999, ISSI published a volume entitled “Magnetospheric Plasma Sources and Losses”, edited by Bengt Hultqvist and collaborators. This volume, which was the result of a two-year preparation and study process within the “ISSI Study Project on Source and Loss Processes”, aimed at giving a comprehensive view of what we knew at that time of Earth’s magnetospheric plasma sources and losses. To reach this ambitious objective, the team had divided the Earth’s plasma environment into specific regions, and in each region the budget of sources and losses of plasma and energetic particles was established, based on the number of spacecraft investigations available. For the sources, essentially two were considered, the ionosphere and the solar wind, and the circulation paths by means of which these two sources feed each region were traced.

Approximately one and a half decade later, it seemed relevant to revisit this issue of plasma sources. Indeed, since the late 1990’s comprehensive results from several orbital missions to the intrinsic planetary magnetospheres of the solar system have become available: Galileo at Jupiter, Cassini at Saturn, and more recently Messenger around Mercury. This is the reason why, following a suggestion by Andrew F. Nagy, the directors of ISSI decided to take advantage of this host of space missions to the planets to study the budget of plasma sources not only for the Earth, but this time for all intrinsic magnetospheres in our solar system. To this end, an ISSI workshop gathering over 40 of the best specialists working on these topics was held in Bern from September 23rd to 27th, 2013, with the task of performing a study of magnetospheric plasma sources in the solar system, and of preparing the writing of a comprehensive book on the subject.

In this perspective, the workshop participants had to face and manage the broad diversity of the subject: first, the diversity of the objects to be considered, from Mercury to Neptune, but also, and above all, the diversity in the sources of the plasmas themselves. While for Earth in 1999 we had, and still have a few years later, to consider only two plasma sources,

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ionosphere and solar wind, in our visit to all solar system magnetospheres we had to include new and complex plasma sources: satellites and rings (at the giant planets), or the planetary surface itself (for Mercury), some of which actually happen to be the dominant sources.

This book reports on our findings along this full tour of the solar system performed by the workshop participants. It starts with two introductory chapters which set the stage and provide the basic tools for our visit to solar system magnetospheres.

In the first introductory chapter, Rick Chappell provides a historical perspective on the study of plasma sources at Earth, showing in particular how our understanding of the ionospheric source evolved and how it became understood to be more and more important with time, and has to be considered now at least on equal footings with the solar wind source. His chapter teaches us how the availability of new space data and progress in simulations transformed our view of plasma sources: a lesson certainly to be kept in mind for all other magnetospheres.

In the second chapter, Kanako Seki and her co-authors provide an overview of the main physical processes that are at work in the expression of sources, transport and losses in the different regions of a magnetosphere and at various energies. The chapter also nicely summarizes the main equations used for the description of these processes, and the main types of modeling tools that have been developed to simulate them. In that way it provides us with the “tool box” that we need to start our exploration of the solar system and understand the data and models.

This exploration is performed from closest to the Sun outwards, and therefore starts with the planet Mercury. Jim Raines and co-authors use some of the latest data from the Messenger orbiter to visit the plasma sources and the dynamics of this tiny magnetosphere, where the influence of the solar wind is dominant, but also where the direct interaction of magnetospheric particles and fields with the exosphere and surface of the planet plays a role like nowhere in the solar system, except maybe at Jupiter’s satellite Ganymede. The very short time scales within which the magnetospheric configuration and the plasma domains of this magnetosphere are reconfigured are also unique in the solar system.

The next object in our exploration is planet Earth: Dan Welling et al. review the progress made in our understanding of Earth’s plasma sources and subsequent transport, acceleration and loss processes since the comprehensive ISSI book of 1999. They consider both the observational and the modelling advances achieved since that time, and establish a new reference for the description of Earth’s basic plasma processes.

The book then moves on to the exploration of giant planets, starting with Jupiter. As Bolton et al. write in their introduction to this chapter, the Jupiter system is “a world of superlatives”: biggest planet in the solar system, strongest magnetic field, largest magnetosphere, and with the most intense plasma sources. Jupiter is dominated by the Io plasma source, which under the effect of the planet’s centrifugal action generates a large plasma disc. Given this, Jupiter is not just the largest magnetosphere, it is also the closest object to a proto-planetary disk we have at hand in our solar system, and to some extent it bridges the gap between planetary sciences and astrophysics. The chapter summarizes the different plasma sources associated with this fascinating object, and the way they are transported and lost from their regions of origin to the outer edges of the magnetosphere.

Saturn, Jupiter’s sister planet and our solar system’s second gas giant by its size, is described in the next chapter by Blanc et al. Just as the Saturn system is diverse in terms of the objects it includes, its plasma sources display a broad diversity, which has been explored in considerable detail by Cassini since it went into orbit around Saturn in July 2004. The rings and satellites all contribute to its plasma sources, but the space exploration of Saturn revealed, quite unexpectedly, that the dominant source is the tiny satellite Enceladus. Even

Titan, the largest moon in the system and the only one with a thick atmosphere, plays a minor role compared to it. So, like Jupiter, Saturn is dominated by a single source.

Uranus and Neptune, our two ice giants at the outskirts of the solar system, are described by Norbert Krupp in the final chapter of the book. These two planets are by far the least well known, since what we know of them only comes from the fly-bys of Voyager 2 in 1986 and 1989. The Voyager data suggest that plasma at Uranus is produced mainly by its hydrogen corona with a likely complement from its ionosphere, whereas at Neptune the dominant source seems to be associated with its satellite Triton.

In the remainder of his chapter, Norbert Krupp offers a final review of all the planetary plasma sources explored by the book, emphasizing the main similarities and differences between them. Overall, one sees that more or less all the same categories of sources are acting at the different planets, but the dominant ones vary strongly from one planet to another. We hope this book will provide the reader with a good opportunity to visit this variety of sources, and to contemplate the diversity of their expressions.

Before closing this foreword, we would like to thank the Directors and Science Committee of ISSI for their support to this project, and to express our warmest appreciation to the wonderful staff of ISSI, ISSI's science programme manager Maurizio Falanga, Jennifer Fankhauser, Andrea Fischer, Saliba F. Saliba, Irmela Schweizer, Silvia Wenger, and all their colleagues, whose kindness and dedication make ISSI such a convivial and effective place to interact, exchange ideas and work. This book would not have been possible without all of them.

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