MAGNETOSPHERIC PHYSICS (Phys F672) - Spring 2014

Instructor: Antonius Otto

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Course Website: http://how.gi.alaska.edu/ao/msp/index.html

Location and time: REIC 138, MWF 10:30-11:30 am

Scope and Contents of the Course:

Planetary magnetospheres are a unique plasma system in many respects. The dynamics of the magnetosphere determines the plasma environment of the planet and controls the physics of the ionosphere. Geomagnetic storms and substorms cause the magnificent auroral displays which we observe at high geomagnetic latitudes. Magnetospheres are a highly inhomogeneous and nonlinear plasma environment in which plasma and magnetic field properties vary over many orders of magnitude. In situ satellite observation make the Earth's magnetosphere probably the best studied plasma environment for our understanding of fundamental plasma processes such as microscopic plasma processes, equilibrium configurations, plasma instabilities, particle acceleration, highly nonlinear eruptive plasma processes, and global dynamics which involves the interaction of various regions of the magnetosphere. Compared to Earth's magnetosphere, observations of the giant magnetospheres of Jupiter and Saturn demonstrate fascinating differences in the global dynamics caused by size, rapid rotation and mass loading from planetary satellites.

The course will introduce these various aspects of magnetospheric physics with a systematic discussion of the structural elements of the magnetosphere, their dynamics, and of the relevant plasma physics. This will include basic aspects like particle dynamics and equilibrium theory as well as more advanced concepts like non-local instability processes and nonlinear dynamics. The course will combine observational results with the relevant plasma physics and theory. Analytic theory is limited with respect to the nonlinear processes. It is offered to provide plasma simulation codes to demonstrate and visualize some of these processes.

(Prerequisites: Plasma physics recommended; Graduate standing or permission of instructor; 3 + 0 credits)

Conduct of the Course:

For most of the class a web manuscript will be provided. Most supplemental material can be found in the textbook by Baumjohann and Treumann, *Basic Space Plasma Physics*. Further information is taken from the texts by Parks, *Physics of Space Plasmas*, by Kivelson and Russel (ed.), *Introduction to Space Physics,* and by Treumann and Baumjohann, *Advanced Space Plasma Physics*. No textbook currently available covers all relevant aspects of magnetospheric physics. Additional original literature will be provided as necessary. The simulation codes will be written in FORTRAN and access to computer resources and visualization software (IDL) can be provided if necessary.

Homework will be mostly analytical. Some exercises in the second half of the course may make use of a provided simulation codes. Every student is expected to make a short presentation on a specific topic which may be the presentation of a specific research paper or of a simulation project.

There will be a midterm test and a final exam.

Grading Policy:

Homework: 50%; Project: 20%; Final exam: 30%

There will be no +/- grades.

Textbooks:

Baumjohann and Treumann, *Basic Space Plasma Physics*, Imperial College Press (1997, 2012): A good introduction to many aspects of space plasma physics. The focus of this book is more on the plasma physical aspects compared to other books in the list. Magnetospheric physics is addressed in various parts of the book. The combination with the more advanced volume *Advanced Space Plasma Physics* by Treumann and Baumjohann provides a very thorough graduate level course in space plasma physics.

Parks, *Physics of Space Plasmas*, Addison-Wesley (1991, 2003): A good introduction to many aspects of space plasma physics. These include single particle dynamics, electromagnetic fields, plasma waves and discontinuities, and simple instabilities. The book has some shortcomings particularly in several areas of plasma physics. It has also limitations in the coverage of the various regions of the Earth's magnetosphere.

Kivelson and Russell (eds.), Introduction to Space Physics, Cambridge University Press (1995): A good introductory text book of various topics of space and magnetospheric physics. The book presents a very good phenomenological overview of various aspects of magnetospheric physics but it has shortcomings in many aspects of the more advanced plasma physics.

Gurnett and Bhattacharjee, Introduction to Plasma Physics: With Space and Laboratory Applications, Cambridge University Press (2005): A systematic discussion of plasma physics. Magnetospheric physics is introduced through various applications but not the focus of this book.

Melrose, Instabilities in space and laboratory plasmas, Cambridge University Press (1989): A systematic discussion of plasma theory, however, with focus on homogeneous plasmas, kinetic processes, and plasma instabilities.

Krall and Trivelpiece, Principles of Plasma Physics, San Francisco Press (1986): Very detailed text on plasma physics but not particularly written for space plasmas. While coverage of traditional plasma physics is excellent, it also lacks many of the nonlinear aspects of plasma theory.

Other: **Gombosi**: Physics of the Space Environment, Cambridge University Press (2004); **Kallenrode**: Space Physics: An Introduction to Plasmas and Particles in the Heliosphere, Springer (2005); **Schindler**: Physics of Space Plasma Activity, Cambridge University Press (2006).

Schedule of contents (each chapter represents about a week of material with some variation):

1. **Introduction** (History of the magnetosphere, Structure of the magnetosphere, Coordinate systems)
2. **Basic Plasma Properties** (First principles, Kinetic plasma equations, Fluid plasma, Plasma parameters)
3. **Electric and Magnetic Fields in Space** (Magnetic fields, Electric fields)
4. **Particle Dynamics** (Motion in electromagnetic fields, Adiabatic invariants, Particles in the magnetosphere)
5. **The inner Magnetosphere** (Trapped particles and drifts, The ring current)
6. **The Bow Shock and the Magnetosheath** (Solar wind, MHD discontinuities and shocks, The bow shock and the magnetosheath
7. **The Magnetopause** (Basic properties and observations, Kelvin-Helmholtz and tearing modes, Magnetopause structure and reconnection, Cusp and mantle)
8. **The Quiet Magnetotail** (Observations, properties, Equilibrium configuration, Convection in the magnetotail)
9. **Magnetospheric Activity** (Magnetophere-ionosphere coupling, Magnetic indices, Substorms, Magnetotail dynamics, Magnetic storms)
10. **Other Planetary Magnetospheres** (Mercury - the small cousing of Earth, Jupiter and Saturn - fast rotation and mass loading)

The following policies and services are included because they are mandated for UAF course syllabi:

- Attendance and class participation (questions, comments etc.) are strongly recommended.
- A make-up exam will be offered if attendance of the final exam was not possible.
- Homework is expected to be handed in on time and plagiarism is strongly discouraged.
- If needed computer access and access to IDL can be provided.
- The instructor will work with the Office of Disabilities Services (203 WHIT, 474-7043) to provide reasonable accommodation to students with disabilities.