AS 703 Introduction to Space Physics – Fall 2016

Instructor: Prof. Merav Opher – mopher@bu.edu; *Office: CAS Room 514F, ph.:* (617) 358-6385 *Regular Office Hours*: Tuesday 2-3pm; Wednesday 1-2pm
Lectures (A1) — Tuesday, Thursday; 09:30 pm – 11:00am, CAS Room 500

Required Texts:
Physics of Solar System Plasmas, by Thomas E. Cravens (Cambridge University Press. ISBN-13: 9780521611947, paperback)

Space Physics, An Introduction to Plasmas and Particles in the Heliosphere and Magnetospheres, by May-Britt Kallenrode published by Springer
http://www.springer.com/us/book/9783662044438;
Available at the Barnes and Nobles bookstore and Amazon.

Other Resources to be used:

- *Physics of the Space Environment, by T. Gombosi, published by Cambridge Univ. Press. http://www.cambridge.org/US/academic/subjects/earth-and-environmental-science/planetary-science-and-astrobiology/physics-space-environment?format=PB*

- *Introduction to Plasma Physics: with Space and Laboratory Applications, by D. A. Gurnett and A. Bhattacharjee published by Cambridge Univ. Press http://www.cambridge.org/US/academic/subjects/physics/plasma-physics-and-fusion-physics/introduction-plasma-physics-space-and-laboratory-applications*

Course Objectives and Scope: This course is designed to introduce space physics to students entering the astronomy graduate program, and to other students interested in research in space physics. The goal is to provide students with sufficient background knowledge for them to be able to read research articles and understand research colloquia and place them in their context in the field. This is necessarily a survey course that will introduce the main areas of space physics research and provide some foundation of our understanding. For students in the astronomy graduate program, this course is considered preparatory to the comprehensive examinations. Since this region is predominantly filled by plasma and electromagnetic energy, the beginning of the course will be dedicated to learning plasma physics. The emphasizes through out the course will be on understanding the major physical processes and concepts. These processes are universal and applicable to other astrophysical settings as well. The main difference from astrophysical systems is the *in-situ* data from several spacecrafts that will exemplify each process. The homework will deepen your understanding by asking you to explore some of the mathematical aspects of each concepts.

Level of Presentation and Pre-requisites: Students normally take this course in their first year of graduate study, so there are no graduate-level prerequisites. However, the presentation will assume a good grasp of the principles encountered in undergraduate physics, particularly in electromagnetic theory, classical mechanics, and to a lesser extent in thermodynamics and statistical mechanics. Physics of fluids concepts will be introduced.

As this course is recommended for students preparing for the astronomy comprehensive exams, I will try to emphasize physical insight, application, and problem solving rather than spending a lot of time on formal derivations. These can be found in texts. Of course I welcome any student who wants to learn about space physics whether or not they are preparing for the astronomy comps. However, students not in the graduate program in astronomy are urged to discuss their participation in the course with the instructor.

Course Content: This course is concerned primarily with phenomenology, and with the physical processes underlying this phenomenology. This approach complements that taken in Cosmic Gas Dynamics (AS726) and Cosmic Plasma Physics (AS727) that are both structured around theory. After an introduction to plasmas, we will discuss the basic morphology and underlying physics of the sun and solar wind, move on to planetary atmospheres, then ionospheres, and finally magnetospheres. A detailed syllabus is provided overleaf.

Grading

• Problem Sets (35% of grade)
There will be 6 problems sets – see the schedule bellow for the dates where approximately the problems will be given to be returned two weeks after. These sets will develop your problem solving skills and will prepare you for the midterm and final exams. Solutions will be handed out at the time of an assignment's due date in order to provide immediate feedback. Hence, *no extensions or late problem* sets will be accepted. Students may work in groups but must write up solutions individually. Recommendation: students should initially attempt problems individually. To receive full credit on a problem, a problem set must include a reasonably clear explanation of the method used to obtain a solution.

• Midterm test in class (30% of grade)

• Final exam (35% of grade)

Exam dates: Midterm – Tuesday - October 18 (in class),

Final: Tuesday - December 20 (in class)

<u>Lecture Outline</u>
- more details bellow – the chapters indicated are from the required text. When the other two textbooks will be used I will indicate in class.

September 06 – Class 1 – What is a plasma – *Ch 1 MB*
September 08 - Class 2 – Charged particles in Electromagnetic Fields – *Ch3 TEC; Ch 2 MB;*
*September 13; 20 *no class*
September 15 - Class 3 – Drifts of particles in Electromagnetic Fields – *Ch3 TEC; Ch 2 MB*
September 22 - Class 4 – Adiabatic Invariants - *Ch3 TEC; Ch 2 MB - Problem Set #1*
September 27 - Class 5 – Basic equations of MHD – *Ch4 TEC; Ch 3 MB*
September 29 - Class 6 – Magnetohydrostatics – *Ch4 TEC; Ch 3 MB*
October 04 - Class 7 – Magnetohydrodynamics – *Ch4 TEC; Ch 3 MB*
October 06 – Class 8 – Magnetohydrodynamics – *Ch4 TEC; Ch 3 MB - Problem Set #2*
October 11 – BU Monday
October 13 - Class 9 – Reconnection *Ch4 TEC*
October 18 – Class 10 – Reconnection/Plasma Waves *Ch4 TEC Ch 4 MB*
Sun /Solar Wind – *Ch6 TEC*
October 20 – Class 11 – Sun/Solar Wind - *Ch6 TEC; Ch 4 MB ; Problem Set #3*
October 25– Class 12 – Interplanetary Magnetic Field *Ch6 TEC Ch 5 MB*
October 27 – MID TERM
Novemb 01 – Class 13 – CMEs and Flares/Space Weather; *Ch6 TEC Ch 5 MB*
Novemb 03 – Class 14 – Solar Energetic Particles - *Ch6 TEC Ch 6 MB; Problem Set #4*
Novemb 08 – Class 15 – Particles at Shocks/Galactic Cosmic Rays; *Ch6 TEC Ch 6 MB*
Novemb 10 – Class 16 – Terrestrial Magnetosphere; *Ch8 TEC Ch 7 MB*
Novemb 15 – Class 17 –Terrestrial Magnetosphere –*Ch8 TEC Ch 7 MB; Problem Set #5*
Novemb 17 – Class 18 –Terrestrial Magnetosphere – *Ch8 TEC; Ch 7 MB*
Novemb 22 – Class 19 – Ionosphere - *Ch7 TEC Ch 8 MB*
Novemb 29 – Class 20 – Ionosphere - *Ch7 TEC Ch 8 MB*
Decemb 01 – Class 21 – Magnetosphere-Ionosphere coupling – *Ch7 TEC; Problem Set #6*
Decemb 06 – Class 22 – Solar Wind Interaction with NonMagnetic Planets *Ch7 TEC*
Decemb 08 – Class 23 – Magnetosphere of Outer Planets *Ch8 TEC*
Decemb 12-16 study period

TEC: ***Physics of Solar System Plasmas, by Thomas E. Cravens (Cambridge University*** *Press. ISBN-13: 9780521611947, paperback)*

MB: ***Space Physics, An Introduction to Plasmas and Particles in the Heliosphere and*** *Magnetospheres*, by May-Britt Kallenrode published by Springer

December 20 – Final Exam

Academic Conduct: Students are expected to attend all class meetings prepared to participate thoughtfully and actively in class. Unavoidable absences should be discussed beforehand. Unexplained absences require an explanation in a timely manner. Please familiarize yourself with the Boston University GRS Academic Conduct Code:

http://www.bu.edu/cas/students/graduate/forms-policies-procedures/academic-discipline-procedures/ Students are expected to exhibit the highest standards of academic integrity, to accurately represent their own academic accomplishments, and to never behave in a