AS 414 Solar and Space Physics

Instructor: Prof. Merav Opher – mopher@bu.edu; *Office: CAS Room 514F, ph.:* (617) 358-6385 *Regular Office Hours*: Tuesday 3-4pm; Thursday 2-3pm

Lectures (A1) — Tuesday, Thursday; 12:30 pm – 2:00pm, CAS Room 502

Required Texts: *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*

Description

The goal of this course is to provide an introduction to space and solar physics. 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. This course is one of two 400-level astronomy courses that serve as capstone electives for astronomy majors. It is also appropriate for physics majors and engineering students who meet the prerequisites. This course is intended primarily for junior/senior Department of Astronomy undergraduate majors. The course requires no prerequisites in advanced space physics knowledge but does presume undergraduate courses in physics, especially electricity and magnetism, and a thorough background in calculus.

Throughout the course mostly the required text book will be used. However, since its heavy on the concepts and light on the derivations; the other two books will complement – I will indicate each portions will be used as well as provide my notes.

Exam dates: **Midterm – Tuesday - March 15** (in class), Final Tuesday., May 3 12:30pm-2:30pm

Prerequisites:

PY 355 or equivalent (Intro to Partial Differential Equations, vector calculus, transform theory (i.e., Fourier). You should know the material from PY 251, 252 or 211, 212 well and, preferably have a junior level Intro to Electromagnetics or circuits class.

<u>Grading</u>

• 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)

<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.

January 19 – Class 1 – Chapter 1 – What is a plasma
January 21 - Class 2 – Chapter 2 – Charged particles in Electromagnetic Fields
January 26 - Class 3 – Chapter 2 – Drifts of particles in Electromagnetic Fields
January 28 - Class 4 - Chapter 2 – Adiabatc Invariants *Problem Set #1*
February 02 - Class 5 – Chapter 3 – Basic equations of MHD – Chapter 3
February 04 - Class 6 - Chapter 3 – Magnetohydrostatics – Chapter 3
February 09 - Class 7 – Chapter 3 – Magnetohydrodynamics –Chapter 3
February 11 – no class (sub later on)
February 16 – no class (Monday-schedule at BU)
February 18 – Class 8 – Reconnection/Dynamo *Problem Set #2*
Fabruary 23 – Class 9 – Chapter 4 – Plasma Waves
February 25 – Class 10 – Chapter 4 – Plasma Waves
March 1 – Class 11 - Chapter 5 – Kinetic Theory
March 3 – Class 12 – Chapter 5 – Plasmas Waves - *Problem Set #3*
March 8/10 - Spring Recess
March 15 – Class 13: Mid Term
March 17 – Class 14 - Chapter 5 – Kinetic Theory
March 22 – Class 15 – - Chapter 6 – Sun/Solar Wind
March 24 – Class 16 - Chapter 6 – Sun/Solar Wind

March 29 – Class 17 – Chapter 6 - Interplanetary Magnetic Field/ Plasmas Waves -*Problem Set #4*
March 31 – Class 18 – Chapter 6 – Flares/CMEs/Shock waves
April 05 – Class 19 – Merav away – Spacecraft Design - Dr. Kelly Korreck
April 07 – Class 20 - Chapter 7 – Particle Population in the Heliosphere - Merav away – sub
April 12 – Class 21 – Chapter 7 – Solar Energetic Particles - *Problem Set #5*
April 14 – Class 22 – Chapter 7 – Particles at Shocks/Galactic Cosmic Rays
April 19 – Class 23 - Chapter 8 – Terrestrial Magnetosphere
April 21 – Class 24 – Chapter 8 – Terrestrial Magnetosphere
April 26 – Class 25 - Chapter 9 Planetary Magnetospheres - *Problem Set #6*
April 28 – Class 26 – Last Class – Chapter 9 Planetary Magnetospheres
May 03 – Final Exam

Topics:

1. What is plasma – Chapter 1

2. Charged particles in Electromagnetic Fields – Chapter 2
   - Review of Electromagnetic Theory
   - Particle Motion in Electromagnetic Fields
   - Drifts of Particles in Electromagnetic Fields
   - Adiabatic Invariants

3. Magnetohydrodynamics – Chapter 3
   - Basic equations of MHD
   - Magnetohydrostatic
   - Magnetohydrodynamics
   - Reconnection
   - Dynamo

4. Plasma Waves – Chapter 4
   - Electromagnetic/Eletrostatic Waves

5. Kinetic Theory – Chapter 5

6. The Sun and Solar Wind – Chapter 6
   - Sun
   - Solar Wind
   - Interplanetary Magnetic Field
   - Plasmas Waves
   - Flares and Coronal Mass Ejections
   - Shock waves

7. Energetic Particles in the Heliosphere – Chapter 7
   - Particle populations in the Heliosphere
   - Solar Energetic Particles
   - Interplanetary Transport
   - Particle acceleration at shocks

- Particles at shocks
- Galactic Cosmic Rays

8. The Terrestrial Magnetosphere – Chapter 8
   - Geomagnetic field
   - Topology of the magnetosphere
   - Plasmas and Currents in the Magnetosphere
   - Geomagnetic Disturbances
   - Aurorae
   - Energetic Partciles

9. Planetary Magnetospheres – Chapter 9