PHYS 780 - Solar and Solar-Terrestrial Physics – Fall 2018

Time	Days	Where	Date Range	Instructor
1:00 pm - 2:20 pm	MT	GITC 1403	Sep 04 - Dec 12, 2018	Alexander G. Kosovichev e-mail: alexander.g.kosovichev@njit.edu

In addition to classroom GITC 1403 the course will be delivered via NJIT Webex:
https://njit.webex.com/join/sasha
Course materials will be available for downloading from:
http://sun.stanford.edu/~sasha/PHYS780/SOLAR_PHYSICS/
Primary textbooks:
Stix, M. "The Sun: An Introduction", 2nd edition, Springer 2002
"Introduction to Space Physics", ed. M.G. Kivelson & C.T. Russell, Cambridge Univ. Press, 1995
Grading: 40% homework assignments, 20% quizzes, 40% final presentation
Office hours: by appointment

Lecture plan

1. **Introduction. Course overview.** "Big problems of heliophysics": solar neutrinos, rotation, dynamo, magnetic energy release, coronal heating, solar wind.
2. **The Sun as a star.** General properties, place in the Hertzsprung-Russell diagram. Distance, mass, radius, luminosity, composition, age, evolution, spectral energy distribution.
3. **Tools for solar observations I.** Solar telescopes. Resolution, MTF, seeing. High resolution telescopes. Spectrographs.
4. **Tools for solar observations II.** Measurements of the line shift. Zeeman effect. Magnetic fields and polarimetry.
5. **Tools for solar observations III.** Solar space missions: SOHO, TRACE, STEREO, Hinode, RHESSI, SDO, IRIS. Neutrino telescopes.
6. **Internal structure I.** Stellar Scaling Laws. Standard model. Evolution. Nuclear reactions. Equation of state. Radiative transfer. Quiz #1
7. **Internal structure II.** Stability. Convective energy transfer. Non-standard models. Solar neutrinos, neutrino transitions, MSW effect.
8. **Solar oscillations.** Observations. Theory of p-, g-, and r-modes. Excitation mechanisms.
9. **Principles of Helioseismology I.** Variational principle, perturbation theory. Inversions, sound speed and rotation inferences.
10. **Principles of Helioseismology II.** Local-area helioseismology, ring-diagrams, acoustic imaging, time-distance tomography.
11. **Subsurface structure and dynamics.** Current helioseismology results. Far-side imaging. Meridional circulation. Emerging magnetic flux. Active region dynamics.

12. **Convection.** Granulation, supergranulation, giant cells. Blue shift, models. Energy balance. Superadiabatic layer. Rotational and magnetic effects. Numerical simulations

13. **Differential rotation.** Observations. Heliographic coordinates. Oblateness, quadrupole moment, test of the general relativity. Rotational history. Models of differential rotation.

14. **Solar MHD.** MHD equations, Alfven and magneto-acoustic waves. Instabilities. Shocks. Quiz #2

15. **The Solar Cycle**, Global magnetism. "Magnetic carpet".

16. **Dynamo theory.** Mean-field electrodynamics, dynamo models, 3D MHD simulations.

17. **Magnetic energy release.** Reconnection. Particle acceleration. Observations. Theories of reconnection, current sheets, MHD and plasma instabilities. Acceleration mechanisms.

18. **Solar atmosphere.** The structure of the solar atmosphere, photosphere, chromosphere, corona. Transition region. Chromospheric network, filaments, prominences, spicules.

19. **Sunspots.** Active regions. Flux tubes. Observations. Static models. Flows, Evershed effect. Formation and decay of sunspots. Theories of emerging flux tubes, magnetic buoyancy.

20. **Flares.** Observations. Radiation, radio-, X-, and gamma-rays. Energetic particles. Thin- and thick-target models, evaporation, heat conduction. Radiative and MHD shocks. Moreton waves, "sunquakes".

21. **Corona.** CME. Observations, eclipses. White light corona, Thompson scattering. Coronal heating, heat conduction. Large-scale structure, change with the solar cycle. Coronal mass ejections, shocks.

22. **Solar wind.** Observations. Expansion, Parker's model, high- and low-speed wind. Composition, first-ionization potential effect. Sector structure, current sheet.
    Quiz #3

23. **Magnetosphere.** Interaction of solar wind with the Earth's magnetosphere and planets. Geomagnetic effects.

24. **Ionosphere.** Auroras, substorms. Space weather.

<u>Learning Objectives and Outcomes</u>

The purpose of the course is to introduce the students to several areas of solar and space physics, to the applied physical principles, and the observational methods. This course covers electromagnetic, plasma and nuclear processes from the center of the Sun to the Earth's surface. It will include the solar radiation, the evolution and structure of the Sun, solar activity cycles, cosmic rays, the heliosphere, solar wind, magnetosphere, radiation belts, ionosphere, geomagnetic effects and space weather.

Upon successful completion of this course, the student will be able to

1) Demonstrate comprehensive knowledge and understanding of observational and data analysis methods, theoretical principles and applications of solar and solar-terrestrial physics.

Students will be able to: understand the basic principle of remote sensing by using spectroscopy (e.g. Doppler-shift, line depth, magnetic field and continuum intensity measurements); understand the basic principles of helioseismology, mechanisms and impacts of sunspot cycles, solar flares and eruptions.

2) Describe the additional concepts that are necessary to understand the physical processes ion the Sun and other stars, and their variations with the magnetic activity. Explain the basic concepts of the solar dynamo mechanisms, describe the characteristic features of the solar differential rotation, such as the tachocline, the near-surface rotational shear layer; understand the structure of the meridional circulation, and its role in the solar cycles.

3) Demonstrate skills of locating, digesting, and presenting the contents of published research papers and monographs at the cutting edge of solar and solar-terrestrial physics, and clearly describe the issues at hand.

4) Apply such newly-acquired concepts to heliophysics, astrophysics and space weather research, as well as to broader applications based on observational and theoretical methods, attempt a clarification or synthesis of the latest results in the field.

Academic Integrity

Any student who is disruptive in the classroom will be in violation of the Academic Honor Code and will be reported to the Dean of Student Services. Any student who cheats during a quiz or an examination will be in violation of the Academic Honor Code. The student will automatically fail the course and will be reported to the Dean of Student Services so that further action may be taken. Examples of cheating during a quiz or an examination include, but are not limited to, talking with another student, copying work from another student's work, allowing another student to copy work from your own work, or use of any materials besides the examination paper and a writing utensil.

Missed Quiz or Exam

Students who miss a common quiz or exam will receive a score of zero for that exam unless they present a valid excuse within 7 days of the exam. Students with two or more missing, unexcused common exams automatically fail the course. Students expecting to be absent from a common exam should discuss their situation with their instructor PRIOR TO their absence. In order to qualify for a (rare) "make-up" common exam a student needs to document the reason for not being able to take the test as scheduled (for example, due to an exam conflict or documented illness). Under NJIT policy, the documentation should be presented to the student's instructor AND to the Dean of Students, both of whom must agree to permit a "make-up" exam.