PHY661A: Turbulence in space plasmas (by Supratik Banerjee)

Per Week Lectures: 2 lectures of 1.5 lecture hours

Duration of Course: **Full Semester**

Course Prerequisites: **None, however elementary knowledge of fluid dynamics, classical electrodynamics, basic statistics and computer programming may be useful**

Objectives:

The understanding of turbulence in space plasmas is crucial to explain the efficient mixing, heating and the acceleration of space plasmas (e.g. the solar wind, the magnetospheric plasmas). For the last thirty years, extensive research works have been exploring various aspects of space plasma turbulence e.g. universality, anisotropy etc. with the help of a combination of analytical results, numerical simulations and in-situ data analysis of dedicated spacecraft missions. This course will offer an exposure to the key problems and the ongoing research works of this field. In addition, the students will be trained to study several properties of space plasma turbulence using public in-situ data of different spacecraft.

Contents**: (for 40 lectures)**

(1) Generic introduction to turbulent flows: (6 lectures)

(i) Definition and possible origin(s) of turbulence, fully developed turbulence, Richardson's cascade, Kolmogorov Phenomenology, universality of turbulence. (2 lectures)
(ii) Turbulence in MHD fluids: Iroshnikov-Kraichnan (-3/2) and Marsch (-5/3) phenomenologies. (2 lectures)
(iii) Exact relations for hydrodynamic and magnetohydrodynamic turbulence. (2 lectures)

(2) Space plasmas and their properties: (3 lectures)

(i) A comparative overview of the solar wind, the coronal plasma and the magnetospheric plasmas. (3 lectures)

(3) Cascade and universality in space plasma turbulence: (15 lectures)

(i) MHD scale energy cascade in solar wind turbulence: spectral approach and exact scaling laws, turbulent heating of the space plasmas. (7 lectures)

(ii) Anomalous heating of solar wind: effect of compressibility in the solar wind turbulence. (2 lectures)
(iii) Sub-ion scale turbulence in the solar wind: cascade vs dissipation. (2 lectures)
(iv) Turbulence in magnetospheric plasmas. (2 lectures)
(v) Cascade of helical invariants (cross helicity, magnetic helicity etc.) in space plasmas. (2 lectures)

(4) Anisotropy in turbulent space plasmas: (10 lectures)

(i) Anisotropy of solar wind turbulence: 2D and slab models, critical balance, global vs local mean magnetic field. (7 lectures)
(ii) Analysis of anisotropy for non-stationary solar wind intervals. (3 lectures)

(5) Other topics of space plasma turbulence: (6 lectures)

(i) Reconnection and turbulence (2 lectures)
(ii) Turbulent mechanism of switchback in the solar wind. (2 lectures)
(iii) Stellar dynamos and turbulence (2 lectures)

(6) Throughout the course several assignments based on in-situ data analysis and the associated techniques will be given in a regular manner.

Grading policy**: Project report + presentation**

Reference books:

(i) Magnetohydrodynamic turbulence, Dieter Biskamp (Cambridge University Press, 2008).
(ii) Kivelson M. G. and C. T. Russell, Introduction to Space Physics (Cambridge University Press, 1995).
(ii) The Physics of Fluids and Plasmas, Arnab Rai Chaudhuri (Cambridge University Press, 1998).
(iii) The Solar Wind as a Turbulence Laboratory, R. Bruno and V. Carbone (Liv. Rev. Sol. Phys., 2005).
(iv) Anisotropy in Space Plasma Turbulence: Solar Wind Observations, T. Horbury, R. Wicks and C. Chen.
(v) Compressible turbulence in space and astrophysical plasmas : Analytical approach and in-situ data analysis for the solar wind, Supratik Banerjee (Ph. D. Thesis)
(vi) Other relevant papers and research works.