Introduction to Plasma Astrophysics (PHY684) - First Course Handout
(2024-25 Even semester)

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Course Objectives:

Astrophysical phenomena, from the majestic glowing of stars to the enigmatic dynamics of galaxies, are intricately woven from the fabric of natural plasmas. Delving into these wonders requires a profound grasp of plasma physics—an indispensable tool for unraveling the mysteries of the universe. This course offers a journey of discovery through the intricate tapestry of astrophysical plasma physics.

Starting with a meticulous exploration of single particle motion within plasmas, this course will voyage through the kinetic theory and the fluid models of plasma. With an emphasis on magnetohydrodynamics (MHD), several aspects of solar plasma i.e. the sunspot, solar flare, CMEs, solar wind turbulence will be discussed. In addition, this course also provides an opportunity for hands-on exploration of astrophysical data analysis obtained from both numerical simulations and in-situ spacecraft observations.

Course content: (40 hours)

(1) Introduction to plasmas, basic properties, characteristic length scales and times scales of plasmas, examples of space and astrophysical plasmas (5 lectures)

(2) Single charged particle motions in plasmas, ExB drift, gradient and curvature drifts, adiabatic invariants, van-Allen belt, auroras (6 lectures)

(3) Vlasov's equation and derivation of two-fluid equations, reduction to single fluid magnetohydrodynamics (MHD), Hall and electron MHD models (9 lectures)

(4) Properties of MHD fluids, magnetic tension and pressure, ideal conservation, linear wave modes, linear instability, incompressible MHD and Elsasser variables (7 lectures)

(5) MHD phenomena, reconnection, MHD turbulence phenomenology, MHD dynamos (5 lectures)

(6) Case study: solar plasma, sunspot, solar flare, CME, solar wind etc. (8 lectures)

Course load and grading:

- **3 lecture hours per week (Tuesday and Thursday, 17h15-18h30)**
- Final grade weightage: **2 quizzes (20 %) + Mid-sem (30%) + End-sem (50%)**

Reference books:

(i) Basic Space Plasma Physics, W. Baumjohann & R. Treumann (World Scientific Publishing)
(ii) Plasma physics for astrophysicists, Russell M. Kulsrud (Princeton University Press)
(iii) Compressible turbulence in space and astrophysical plasmas : Analytical approach and in-situ data analysis for the solar wind, Supratik Banerjee (Ph. D. Thesis, 2014)