Indian Institute of Technology, Kanpur

Proposal for a New Course

1. Course No: PHY6XX is requested
2. Course Title: ***Introduction to Plasma Astrophysics***
3. No. of Lectures per week: 3 (L), Tutorial: 0 (T), Laboratory: 0 (P), Additional Hours[0-2]: 0 (A),

   Credits (3*L+2*T+P+A): 09 Duration of Course: Full Semester
4. Proposing Department/IDP : PHY.

   Other Departments/IDPs which may be interested in the proposed course: SPASE, Earth Sciences

   Other faculty members interested in teaching the course: Prof. Sagar Chakraborty, Prof. Sudeep Bhattacharjee
5. Proposing Instructor: Supratik Banerjee and Gopal Hazra (PHY)
6. Course Description:

A) 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 unravelling the mysteries of the universe. This course offers an enthralling journey through the intricate tapestry of astrophysical plasma physics.
Starting with the definition, basic properties and systematic classification of plasmas, an encouraging discussion will be dedicated to various plasma sources and important examples of astrophysical plasmas. Along with a meticulous exploration of single particle motion within plasmas, this course will voyage through the kinetic theory and the fluid models of plasma. In the framework of single fluid model magnetohydrodynamics (MHD), several aspects of solar plasma i.e. the sunspot, solar flare, CMEs, solar wind turbulence will be discussed.
Besides theory, this course also provides an opportunity for hands-on exploration of astrophysical data analysis. Starting from deciphering numerical simulations to unravelling the mysteries hidden within in-situ spacecraft data, students will gain invaluable insight into the tools of modern astrophysics thus aiming at a brilliant career in the understanding of the cosmos.

B) Contents:

S. No.	Broad Title	Topics	No. of Lectures
1.	**Introduction**	Basic properties, characteristic length scales and times scales of plasmas, classification of plasmas, plasma sources, examples of space and astrophysical plasmas	**5**
2.	**Single particle dynamics**	Motion of single charged particle in electromagnetic fields, ExB drift, gradient drift and curvature drifts, adiabatic invariants, van-Allen belt, auroras	**6**
3.	**Kinetic and fluid descriptions of plasma**	Kinetic model of a plasma, introduction to Vlasov's equation and derivation of multi-fluid models; derivation of equations in ordinary magnetohydrodynamics (MHD), extension to Hall and electron MHD models	**9**
4.	**MHD plasma**	Properties of MHD fluids, magnetic tension and pressure, ideal conservation, linear wave modes, linear instability, incompressible MHD and Elsasser variables, reconnection, MHD turbulence, MHD dynamos	**12**

5.	**Solar plasma as an MHD fluid**	Study of solar plasma; sunspot, solar flare, CME, solar wind turbulence, solar dynamo etc.	**8**
		Total number of lectures:	**40**

C) Pre-requisites: None

D) Short summary for including in the Courses of Study Booklet: definition and classification of plasmas, motion of a single charged particle in a plasma, kinetic theory of plasma, derivation of the multi-fluid equations, reduction to the simplest single fluid magnetohydrodynamics (MHD) model, properties of an MHD plasma, ideal invariants of MHD, linear modes and linear instabilities of MHD, case study with solar plasma as an MHD fluid: sunspot, solar flare, CME, solar wind turbulence, solar dynamo etc., hands-on exploration of astrophysical data analysis

7. Recommended books:

   (i) Basic Space Plasma Physics, Wolfgang Baumjohann and Rudolf A. Treumann (World Scientific Publishing, 1996)

   (ii) The Physics of Fluids and Plasmas, Arnab Rai Chaudhuri (Cambridge University Press, 1998)

   (iii) Plasma physics for astrophysicists, Russell M. Kulsrud (Princeton University Press, 2004)

   (iv) Compressible turbulence in space and astrophysical plasmas : Analytical approach and in-situ data analysis for the solar wind, Supratik Banerjee (Ph. D. Thesis, 2014)

Dated: 15 March, 2024.

Proposer: Supratik Banerjee and Gopal Hazra

Gopal Hazra

Dated: 15/03/2024 DPGC Convener (PHY):____________________

The course is approved / not approved

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Chairman, SPGC

Dated:________________________________