# Seminar

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# Institute for Plasma Research

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**Title:** Turbulent dynamo action in a 3-dimensional magnetohydrodynamic plasma

**Speaker:** Mr. Shishir Biswas
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**Date:** 31st July 2024 (Wednesday)

**Time:** 11.00 AM

**Venue:** Seminar Hall, IPR

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## Abstract

Turbulence is a ubiquitous phenomenon in nature and is considered to be one of the unresolved issues in physics. Turbulent velocity fields are known to play a crucial role in the production and maintenance of multi-scale magnetic fields in a variety of astrophysical objects. Significant challenges exist in the understanding of the production of mean, or large-scale and small scale magnetic fields in celestial and astrophysical entities. Dynamo action **[1]**, provides a potential explanation for the mechanism underlying this generation of magnetic energy from the kinetic energy via velocity fields. It is thus essential that the velocity fields possess sufficient dynamics to produce dynamo action. However, not all velocity fields have the ability to generate dynamo action, as demonstrated by Crowling's and Zeldovich's anti-dynamo theorems.

In this Thesis work, we have initially examined the turbulent characteristics of different flows in both two and three dimensions **[2, 3]**. The influence of fluid helicity on kinematic dynamo action has been studied utilizing these flow fields. Using direct numerical simulation, we demonstrate that by controlled injection of fluid helicity, a systematic route emerges that connects "non-dynamo" to "dynamo" regime **[4]**. However for a nonlinear dynamo or self-consistent dynamo model, the nonlinear effects start to change the flow (once the magnetic field is large enough) to stop further growth in magnetic field energy, i.e, the flow and magnetic field "back react" on each other leading to nonlinear saturation. The influence of helical and non-helical drive in such a nonlinear or self-consistent dynamo model is shown to have some crucial dynamics **[5]**. Evidence of small-scale dynamo activity is found for both helical and non-helical drives **[5]**. The spectrum analysis shows that the kinetic energy evolution adheres to Kolmogorov's $k^{-5/3}$ law, while the magnetic energy evolution follows Kazantsev's $k^{3/2}$ scaling. These scalings are observed to be valid for a range of magnetic Prandtl numbers ($P_m$) **[5]**. Statistical analysis is found to support our numerical finds. We have also investigated the shear dynamo action using a kinematic dynamo model. Specifically, we find that in the absence of shear flows, the considered non-helical flow is unable to induce exponential amplification of magnetic energy. Interestingly, when the flow shear is introduced, it is found that the small scale non-helical base flow produces magnetic energy that grows exponentially with time **[6]**.

We have performed the above said studies using an in-house developed, multi-node, multi-card GPU based weakly compressible 3D Magnetohydrodynamic solver (GMHD3D) **[7, 8]**. Details of this study will be presented.

References:

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3. ***S. Biswas** & R. Ganesh, Manuscript under Preparation (2024).*
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5. ***S. Biswas** & R. Ganesh, http://arxiv.org/abs/2407.14810 Submitted to Scientific Reports (2024).*
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7. ***S. Biswas**, R. Ganesh et al., Conference Proceedings of 28th IAEA Fusion Energy Conference, (2020).*
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