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HIGH PERFORMANCE *COMPUTING* NEWSLETTER

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INSIDE THIS ISSUE
(2 Pages)

Can Kinetic Helicity Affect Fluctuation Dynamos?

Shishir Biswas (PhD Student, Plasma Devices Theory and Simulation Division, IPR)
Email: shishir.biswas@ipr.res.in

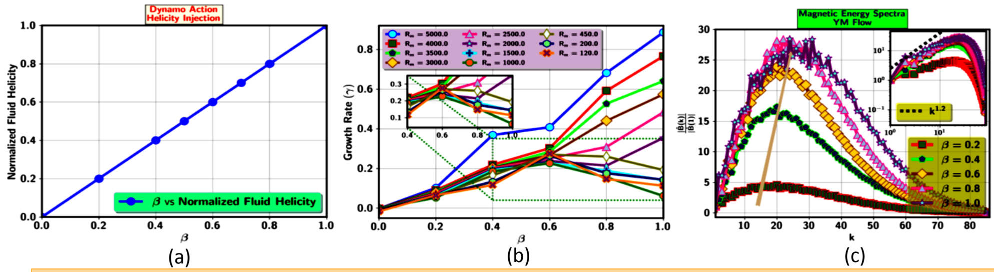


Figure 1: (a) Normalized fluid helicity as a function of β for Yoshida-Morrison (YM) flow. (b) A notable transition from non-dynamo regime to dynamo regime is observed in magnetic energy growth rate, at the cost of fluid helicity injection. (c) Magnetic energy spectrum in linear scale [Inset: log scale].

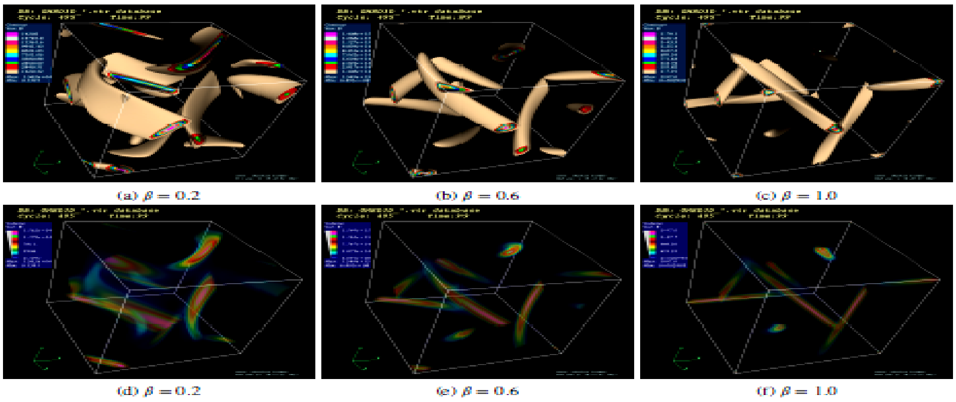


Figure 2: (a..c) Visualization of three-dimensional (3D) magnetic energy iso-surface for different β values. Iso-surfaces are seen to be converted from twisted "ribbon" to "cigar" like nature. (d..f) Same but the visualization is performed using volume rendering technique. This type of visualization helps to understand the internal structures of the Iso-surfaces.

The generation of small scale, mean or large scale magnetic fields in the cosmos and in astrophysical bodies is an important long standing problem in astrophysical plasmas. Parker's theory [1] proposes dynamo action as a possible mechanism for this multi-scale magnetic energy growth. Types of dynamos include the large scale dynamo (LSD) or mean field dynamo [generated magnetic fields are correlated in larger scale lengths than the underlying turbulence], the small scale dynamo (SSD) or fluctuation dynamo [generated magnetic fields are correlated in shorter scale lengths that are smaller than the forcing scale], the fast dynamo [magnetic energy growth rate remains finite in the zero resistivity limit], the slow dynamo [magnetic diffusion plays an important role], the kinematic dynamo [magnetic feedback on velocity field is neglected], the self-consistent dynamo [magnetic feedback is taken into consideration that leads to non-linear saturation], and so on [2]. Among these models, in a kinematic fast dynamo model, the magnetic field grows exponentially in the limit of low plasma resistivity due to a chaotic plasma flow that stretches and folds back the weak ambient magnetic field lines and amplifies it in the process. For most of the work considered in the past, chaotic, helical Arnold-Beltrami-Childress [ABC] flow has been used for studying dynamo action, especially for the kinematic fast dynamo model. It is also known that the exponential growth of magnetic energy is associated with the generation of "cigar" or "ribbon" like magnetic iso-surfaces for ABC flow. These magnetic structures are indicative of a high degree of magnetic energy localization.

> ***"High resolution DNS using GMHD3D code helps to identify a systematic route that connects "non-dynamo" to "dynamo" regimes. Further, it provides an evidence that kinetic helicity has a major impact on fluctuation dynamos"***

The role of fluid or kinetic helicity on the onset of dynamo action is a reasonable question to ask. According to conventional understanding, for a LSD or mean field dynamo, a lack of reflectional symmetry (e.g., non-zero fluid or kinetic helicity) is pre-requisite for the onset of dynamo action, whereas for SSD, it is not. Nonetheless, a comprehensive study of the correlation between injected fluid helicity and onset/growth of small-scale kinematic fast dynamo action is necessary to fully comprehend the physics of dynamos

To address this physics issues, we have recently upgraded an existing compressible three-dimensional magnetohydrodynamic solver developed in house, to multi-node multi-GPU architecture [GMHD3D] for better performance [3]. Scaling studies have been performed and super-linear speedup across 32 P100 GPU cards has been achieved [3]. We have analyzed kinematic dynamo model using a flow recently proposed by Yoshida and Morrison (YM) [4]. An interesting and useful aspect of this flow is that, it is possible to inject finite fluid helicity in the system, by systematically varying certain physically meaningful parameter (See Fig. 1a). Moreover, this flow has the unique virtue of connecting the classes of flows in quasi-2 and 3-dimensions topologically. Starting from YM flow as a prototype, we show, through the use of a basic kinematic fast dynamo model and direct numerical simulation (DNS), that a systematic route from the "non-dynamo" to the "dynamo" regime develops when finite fluid helicity is injected into the system (See Fig. 1b) [5]. Time-averaged magnetic energy spectra are computed for different levels of injected fluid helicity, and it is found that the spectra have a visible maximum at a intermediate mode number, which is characteristic of SSDs (See Fig. 1c) [5]. We have found that injecting fluid helicty transforms an magnetic iso-surface that looks like a "twisted ribbon" or "sheet" into a conventional "cigar-shaped" fast dynamo iso-surface (See Fig. 2) [5]. All simulations were executed at 2563 grid resolutions, and a single run required 55.18 GPU hours on 4 P100 GPU cards.

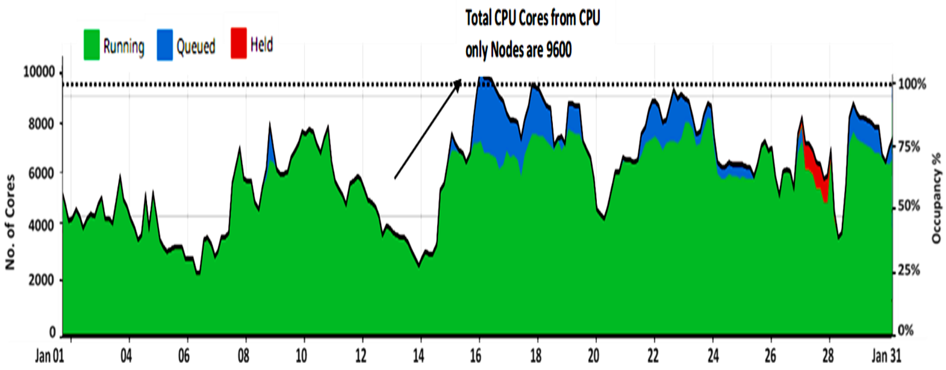
To conclude, with high resolution and at high magnetic Reynolds number, we investigate a systematic route that connects "non-dynamo" to "dynamo" regime. For the flow considered here, we demonstrate how, helical structure of the flow does strongly controls the SSD growth and spectral structure. Our finding is in complete contrast to the conventional thoughts that the kinetic helicity does not affect the dynamics of small-scale dynamos. Our numerical findings throw light on one of the long standing astrophysical problem, regarding the role of fluid helicity in the context of short scale or fluctuation dynamos.

References:

1. *Parker, E.N., 1955. Hydromagnetic dynamo models. The Astrophysical Journal, 122, p.293.*
2. *Rincon, F., 2019. Dynamo theories. Journal of Plasma Physics, 85(4), p.205850401.*
3. ***S Biswas**, R Ganesh et al. "GPU Technology Conference (GTC-2022)", https://www.nvidia.com/en-us/on□demand/session/gtcspring22-s41199/.*
4. *Yoshida, Z. and Morrison, P.J., 2017. Epi-two-dimensional fluid flow: A new topological paradigm for dimensionality. Physical review letters, 119(24), p.244501.*
5. ***Biswas, S.** and Ganesh, R., 2022. Revisiting Kinematic Fast Dynamo in 3-dimensional magnetohydrodynamic plasmas: Dynamo transition from non-Helical to Helical flows. https://doi.org/10.48550/arXiv.2211.12362 [Manuscript under review 2023].*

ANTYA Utilization: JANUARY 2023

ANTYA Daily Observed Workload



Note: *The red portion of the utilization chart shows the cores being held by the jobs which have occupied the resources but not running and using the allotted resources. This happened during the GPU hardware issue occurred in January and affected some of the CPU nodes.*

ANTYA HPC USERS' STATISTICS— JANUARY 2023

♦ **Total Successful Jobs — 4159**

♦ **Top Users (Cumulative Resources):**

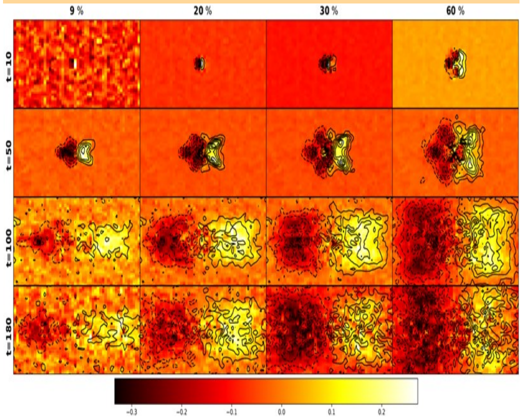
- **CPU Cores** — **Suruj Kalita**
- **GPU Cards** — **Sunil Bassi**
- **Walltime** — **Sunil Bassi**
- **Jobs** — **Anshika Chugh**

Other Recent Work on HPC (Available in IPR Library)

Magnetized Multi-component Plasmas Sheath Characteristics with Three Isothermal ion Species	AKSHAYA KUMAR SHAW
On analysis of scintillator crystal temperature rise for ITER HXR-monitor due to the radiation flash load following the activation of the Disruption Mitigation System	SANTOSH PANKAJKUMAR PANDYA
Preliminaries Results of View Dump for Vertical Electron Cyclotron Emission (VECE) Radiometer	PRABHAKAR TRIPATHI
Development of deep learning models for time series analysis for predicting future sequence of signals at Aditya-U tokamak	RAMESHKUMAR BABUBHAI JOSHI
3D Computational Fluid Dynamics Analysis of PINI Ion Source Back Plate under high heat flux condition	TEJENDRAKUMAR PATEL
Impact of edge biasing on the cross-field transport and power spectra	VIJAY SHANKAR

HPC PICTURE OF THE MONTH

Subcritical turbulence in 3D Yukawa liquids



Pic Credit: **Suruj Kalita**

In the above figure, total velocity field V_x is shown at the mid-Y plane of a rectangular cuboid system. Here, the structure at each subfigure shows the "spot structure", which is a characteristics of turbulent "plane Couette flows". As we increase the strength of perturbation, from 9% to 60%, the spot structure grows and becomes well-defined at later times. In this way we have demonstrated subcritical turbulence, which is observed when a base flow is stable at all the Reynolds number, but non-linearly unstable at higher amplitudes of perturbation. [Ref: S Kalita, R Ganesh, Phys. Fluids 33, 095118 (2021)]

This figure is generated with the data obtained from MPMD-3D (inhouse code) simulation which took around 19 hours on 4 P100 GPU cards.

Acknowledgement

The HPC Team, Computer Division IPR, would like to thank all Contributors for the current issue of *GAṆANAM*.

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