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Gyrokinetic Simulations of Electrostatic Microturbulence in ADITYA-U Tokamak

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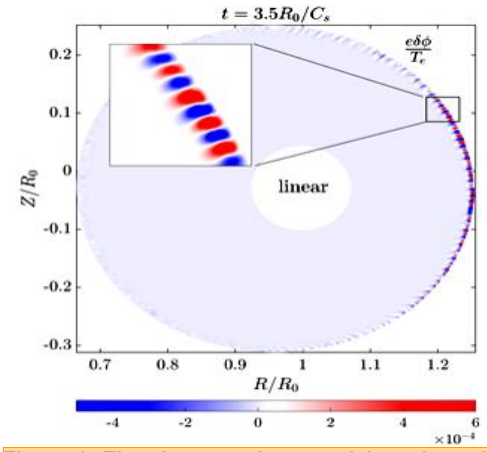


Figure 1: The electrostatic potential on the poloidal plane in the linear phase at time t = 3.5R_0/C_s and the enlarged view of the linear eigenmode structure.

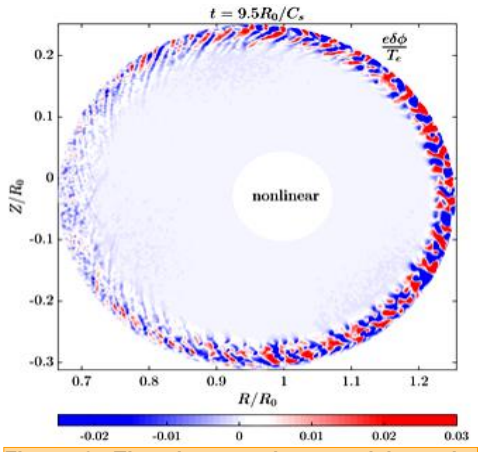


Figure 2: The electrostatic potential on the poloidal plane in the nonlinear phase at time t = 9.5R_0/C_s.

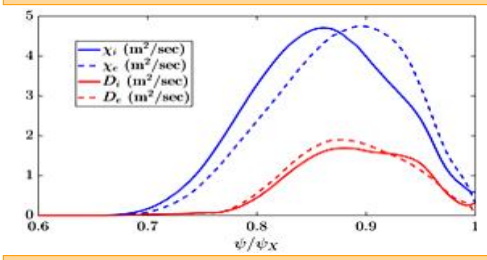


Figure 3: The flux surface variation of the transport coefficients (diffusivity and heat conductivity) for ions and electrons.

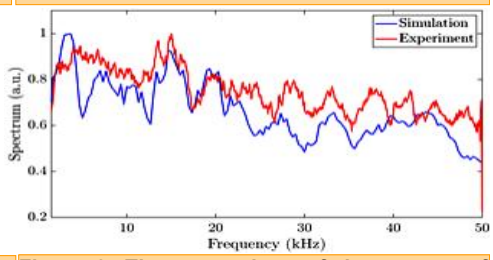


Figure 2: The comparison of the spectra of the electrostatic fluctuations from simulation and experiment near the LCFS.

The global effort to replicate the fusion reaction on Earth, like the Sun and stars, is focused on Tokamak device, which are believed to be promising. ITER, the world's gigantic experimental reactor, aims to harness fusion power. Tokamaks use strong magnetic fields to confine fusion fuel in a torus shape. Out of all the transport processes, the small-scale instabilities, called micro-instabilities, are known to be the primary cause of loss of heat and particle fluxes from the device [1]. Therefore, their understanding is vital for the viability of nuclear fusion. Advancements in high-performance computing have proved that gyrokinetics accurately describes turbulent transport in fusion plasmas. One of the main objectives of these first-principles studies is to project the transport levels from the present fusion experiments to much larger future experiments such as ITER.

ADITYA-U is a medium-sized air-cored tokamak. Since its commissioning in Institute for Plasma Research (IPR), several experiments relevant to the operation of future fusion devices, such as ITER, have been performed [3]. However, there are only a few simulation studies in ADITYA-U. In this work, the first-principles-based global gyrokinetic simulations of electrostatic microturbulent transport are presented for a typical experimental discharge of ADITYA-U tokamak using the ***gyrokinetic toroidal code (GTC)*** *[2]*, which is a nonlinear particle-in-cell code used in the past to study the transport due to microturbulence in various fusion devices. GTC simulations are carried out using the ADITYA-U typical discharge parameters. Kinetic electron effects are retained in the simulations using the fluid-kinetic hybrid model [4], and collisional effects are also considered. Simulations show that the dominant instability is trapped electron mode (TEM) depending upon its structure (see Figure 1) and propagation in the electron diamagnetic direction. As shown in Figure 2, in the nonlinear phase of the simulations, turbulence spread away from the location of linear eigenmode due to the nonlinear mode coupling. The self-generated zonal flow plays a secondary role in the nonlinear saturation of turbulence, which is mainly dominated by the inverse cascade of higher poloidal and toroidal modes to the lower ones. Simulations with and without collisional effects show that collisions reduce transport due to TEM to a certain extent. Figure 3 shows the flux surface variation of the transport coefficients for ions and electrons. The ion diffusivity and electron heat conductivity values at the last closed flux surface (LCFS) are in the ballpark estimate obtained from the experiments. Further, the spectrum of electrostatic fluctuations is broad, as obtained in the experiments (see Figure 4). These findings suggest that TEM driven instability is one of the dominant channels for driving the transport in ADITYA-U.

> ***"GTC simulations in ADITYA-U tokamak reveal trapped electron mode driven micro-instability as a key channel for turbulent transport."***

The presented simulations utilized ***IPR's ANTYA cluster extensively, employing ~1000 cores for ~5 hrs with ~250 GB disk space***. GTC utilized hybrid parallel computing (OpenMP+MPI) with libraries like NetCDF (data writing) and HYPRE (solving matrix equation).

In summary, this work presents the first global gyrokinetic simulations of electrostatic microturbulence in ADITYA-U tokamak. GTC simulations reveal TEM as the dominant transport channel, with collisions reducing turbulence to some extent. Zonal flow does not play a critical role in turbulence saturation; instead, an inverse cascade of higher poloidal and toroidal modes to lower ones acts as the dominant saturation mechanism. For detailed results, refer to [5].

This work is supported by National Supercomputing Mission (Ref. No.: DST/NSM/R&D_HPC_Applications/2021/4), Board of Research in Nuclear Sciences (BRNS Sanctioned No. 39/14/05/2018-BRNS), Science and Engineering Research Board EMEQ program (SERB sanctioned No. EEQ/2017/000164).

References:

1. W. Horton, Rev. Mod. Phys. 71, 735 (1999).
2. Z. Lin et al., Science 281, 1835 (1998).
3. R. Tanna et al., Nucl. Fusion 62, 042017 (2022).
4. ***T. Singh*** *et al., Nucl. Fusion 62, 126006 (2022).*
5. ***T. Singh*** *et al., Nucl. Fusion 63, 056008 (2023).*

Collaborating and Running MATLAB Codes Without a License: Leveraging MATLAB Online with GitHub

In this article, we explore the exciting possibilities of running MATLAB codes using MATLAB Online and collaborating through GitHub. For greater collaboration and accessibility among researchers writing MATLAB codes, this article demonstrates the methods of working with these codes without the need for a license. GitHub facilitates version control while sharing MATLAB codes among collaborators, especially benefiting users working with external users who may not have a MATLAB license. This approach aims to enhance reproducibility without much effort. The remaining workflow series articles will be continued from next issue.

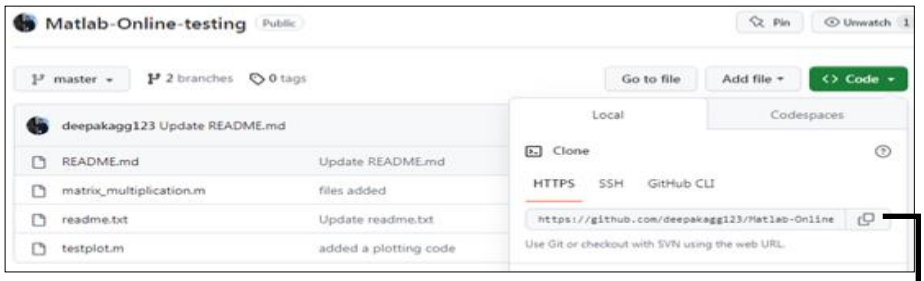
MATLAB Online

It enables users to collaborate on MATLAB coding projects without the need for individual licenses. It includes standard MATLAB functionality and tools with 20 hours of free usage per month. For using MATLAB Online, first create an account at *https://matlab.mathworks.com/*.

GitHub and Linking Your Repository to MATLAB Online

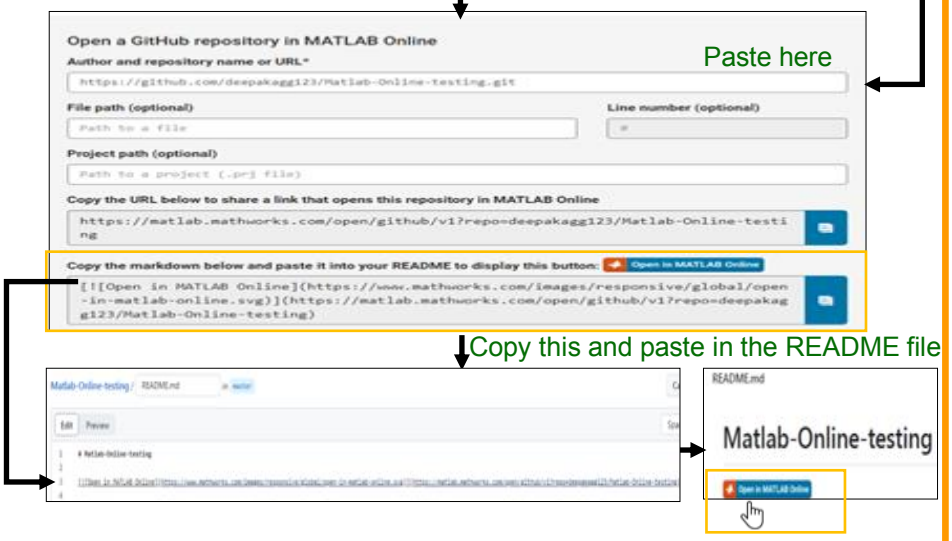
In your GitHub account, create or upload your files from ANTYA either through git or manually in your public repository. To link MATLAB Online with your repository use: *https://www.mathworks.com/products/matlab-online/git.html.*

Step-1: Creating Your Repository

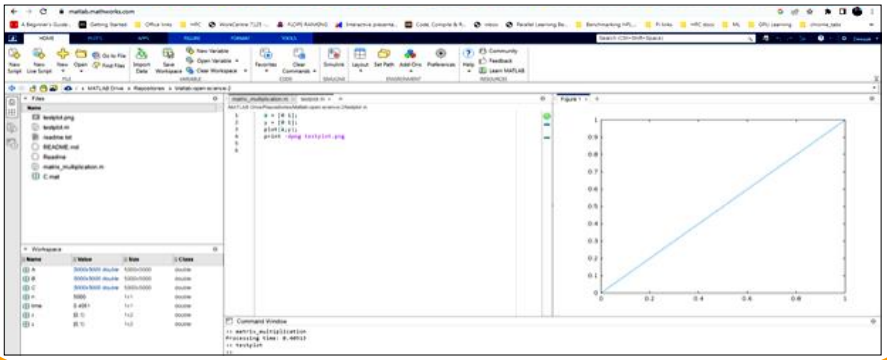


Step-2: Linking Your Repository with MATLAB Online

Open URL: *https://www.mathworks.com/products/matlab-online/git.html.*



Step-3: Opening MATLAB Online from GitHub and Running Code Online



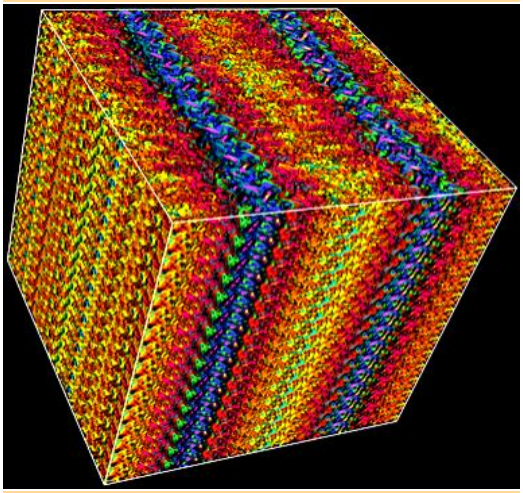
ANTYA UPDATES AND NEWS

1. New Packages/Applications Installed

Modules list remains the same for this month. To check the list of available modules:
$ module avail –l

HPC PICTURE OF THE MONTH

Effect of Flow Shear on the onset of Small Scale Dynamos



Pic Credit: **Shishir Biswas**

This figure represents the magnetic energy iso-surfaces (or dynamo iso-surfaces) in the presence of flow shear in three dimensions. The magnetic energy is concentrated in two bands near the segments with strong velocity gradients. Also Magnetic energy iso-surfaces are mostly dominated by small-scale structures. Hence this is a small scale dynamo (SSD).

(S Biswas and R Ganesh 2023 Phys. Scr.98075607 & S Biswas and R Ganesh, https://doi.org/10.48550/arXiv.2305.19796)

The simulation has been performed using an In-house developed multi-node multi-card weakly compressible magnetohydrodynamic GPU based solver GMHD3D. This simulation of 256^3 grid resolution took 70.526 hrs on 4 P100 GPU cards distributed on 2 GPU nodes of ANTYA Cluster. For this 3D Iso-surface visualization, we have used an open source visualization package VisIt 3.1.2 available on ANTYA and generated on the Visualization node.

TIP OF THE MONTH

Slow Running Jobs in Serial Queue

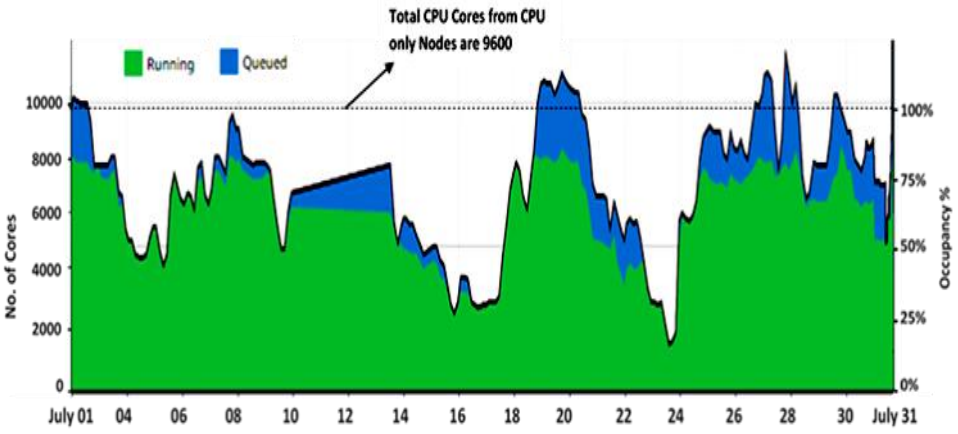
If you notice a drop in job performance affecting the update speed of your output data file, follow below steps to identify one of the potential issues:

- Go to the node on which your job is running
- Use the "top" command to assess resource utilization of your process and other processes.
- Multithreading in your job or other jobs on the same node could be causing the slowdown as they are competing for the same resources.

```
[user@login1 ~]$ ssh node_name
[user@node_name ~]$ top
```

ANTYA Utilization: JULY 2023

ANTYA Daily Observed Workload



ANTYA HPC USERS' STATISTICS—

JULY 2023

- Total Successful Jobs — **4127**
- **Top Users** (Cumulative Resources):

• CPU Cores	Amit Singh
• GPU Cards	Shishir Biswas
• Walltime	Someswar Dutta
• Jobs	Arzoo Malwal

Other Recent Work on HPC (Available in IPR Library)

Investigation of thermal hydraulics performance of Pb-Li in a square duct	Srikanta Sahu
Study on Sheared Flow Instabilities in Rotating Magnetoplasmas under the Beta Plane Approximation	Prince Kumar
Numerical Simulation of an Expanding Magnetic Field Plasma using Cylin- drical 2D3V PIC-MCC Code	Vinod Saini
3D MHD flow analysis in a circular duct with different wall electrical conductivity	Anita Patel
Deconfinement of Runaway Electrons by Local Vertical Magnetic Field Perturbation	Someswar Dutta
Pseudo-spectral solver versus grid-based solver: A quantitative accuracy test using GMHD3D and PLUTO4.4	Shishir Biswas
Artificial Intelligence based Face Recognition: Advancements and Applications	Agraj Abhishek
ION TEMPERATURE DYNAMICS FOR THE EDGE AND SCRAPE-OFF LAYER PLASMA TURBULENCE	Nirmal K. Bisai
Vortex dynamics, Turbulence & Bifurcation in three-dimensional Navier-Stokes fluids: A study using newly developed 3D GPU solver	Shishir Biswas
Effect of stream-wise vortices in the spot formation mechanism at large aspect ratios	Suruj Jyoti Kalita
Interaction between two blobs in scrape-off layer region of Tokamak Plasma	Souvik Mondal
Laser-cluster interaction in an ambient magnetic field	Kalyani Swain
Nonlinear steepening of whistlers in resonant regime	Devendra Sharma
Design, Simulation and Implementation of Structural Support for Cylindrical High Temperature Reactor	Atikkumar N. Mistry

Acknowledgement

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

On Demand Online Tutorial Session on HPC Environment for New Users Available
Please send your request to ***hpcteam@ipr.res.in.***

Join the HPC Users Community
hpcusers@ipr.res.in
If you wish to contribute an article in GANANAM, please write to us.

Contact us
HPC Team
Computer Division, IPR
Email: ***hpcteam@ipr.res.in***