GAṆANAM (गणनम्)

HIGH PERFORMANCE *COMPUTING* NEWSLETTER

INSTITUTE FOR PLASMA RESEARCH, INDIA

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(3 Pages)

Gyrokinetic simulation of short wavelength Ion Temperature Gradient Instabilities in the ADITYA-U Tokamak (Full Paper Available Online)

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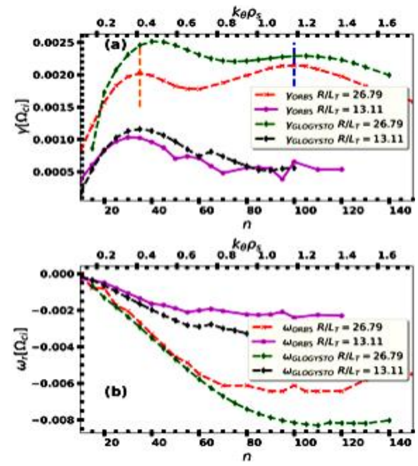


Figure 1: a) Growth rate (γ) and b) real frequency (ω_r) plots using ORB5 and GLOGYSTO.

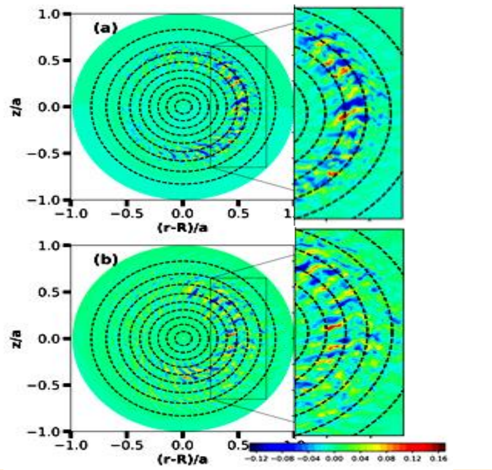


Figure 2: 2D potential structure $\phi - \langle\phi\rangle$ at t[Ω_{ci}^{-1}] = 2.0e5 for R_0/L_T = 26.8 (top) and R_0/L_T = 13.1 (bottom) respectively.

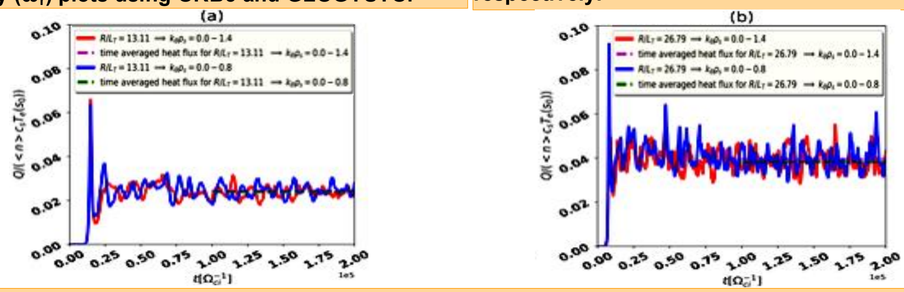


Figure 3: Temporal evolution of (a) normalized heat flux for R_0/L_T = 13.1 for poloidal wave numbers 0.0≤ $k_\theta\rho_s$≤1.4 (red solid line) and R_0/L_T = 13.1 for poloidal wave numbers 0.0≤$k_\theta\rho_s$≤0.8 (blue solid line) capturing only conventional ITG mode (b) normalized heat flux for R_0/L_T = 26.8 for poloidal wave numbers 0.0≤$k_\theta\rho_s$≤1.4 (red solid line) and R_0/L_T = 26.8 for poloidal wave numbers 0.0≤$k_\theta\rho_s$≤0.8 (blue solid line) capturing only conventional ITG mode.

One of the crucial concerns in current fusion research is the mitigation of anomalous transport to enable improved plasma confinement. Instabilities at frequencies lower than the ion gyro-motion frequency and with scale lengths comparable to the ion Larmor radius [1] are thought to be the cause of degradation in plasma confinement, resulting in anomalous transport of energy and particles. The density and temperature inhomogeneities present in a magnetically confined plasma provide the free energy for these modes. For example, it has been observed that even when wavelengths $k_\theta\rho_s$>1, the ion temperature gradient mode (ITG), driven by the temperature gradient of ions, becomes unstable when the background gradients (density and temperature) are extremely sharp [1]. These background gradients tend to drive the instability of short-scale ion temperature gradient modes (SWITGs) [1]. Similarly, trapped electron modes can also exhibit a shorter wavelength branch in the presence of significant gradients [2]. Gyrokinetic simulations have shown that this short-wavelength branch of micro-instabilities essential to understand experimental parameters [3]. Therefore, it is crucial to investigate the nonlinear characteristics of these modes and their contribution to the anomalous transport of energy and particles.

In this work, we address the self-consistent dynamics of SWITGs driven by extremely sharp background gradients, their linear and nonlinear evolution, and their saturation after the onset of zonal flows. This study possibly represents very first analysis performed using a global, gyrokinetic, electrostatic solver that includes adiabatic electrons and non-adiabatic ions. To achieve this, we systematically analyze the linear and nonlinear behavior of the mode for ADITYA-U using ORB5 [4] and GLOGYSTO [5]. The ADITYA-U tokamak, which has recently been upgraded to a divertor configuration [6, 7], is small in size tokamak and is well-suited for investigating micro-instabilities in the presence of density and temperature gradients. Due to steep density and temperature gradients, simulations show that the SWITG mode naturally exists alongside the standard ITG mode in ADITYA-U. From the linear simulation, we find good agreement in growth rate and real frequency values between ORB5 and GLOGYSTO, with variations of less than 25%. Two maxima of growth rate versus mode number are obtained: the first occurs around $k_\theta\rho_s$ ~ 0.4, representing the standard ITG mode, and the second occurs around $k_\theta\rho_s$ ~ 1.2, representing the SWITG mode, as shown in Figure 1. Additionally, using linear stability analysis, we observe that the SWITGs are suppressed for low values of R_0/L_T, i.e., only the standard ITG mode remains unstable. For the ADITYA-U tokamak, nonlinear global simulations with ORB5 are also carried out. The 2D potential structure at t[Ω_{ci}^{-1}] = 2.0e5 for R_0/L_T = 26.8 and R_0/L_T = 13.1 is shown in Figure 2. Nonlinearly, when the SWITG dominates, it is compared with the standard ITG case, where the SWITG is relatively suppressed. The nonlinear contribution of the SWITG mode to the total thermal ion heat transport is found to be minimal due to the increased zonal flow shearing effect resulting in the suppression of transport due to the SWITG mode, even though it may be linearly more unstable than the conventional long-wavelength ($k_\theta\rho_s$<1) ITG mode, as shown in Figure 3. The detailed results of this work are available here [8].

> ***"Our study extensively employs nonlinear simulations to investigate micro-turbulent transport in ADITYA-U, utilizing approximately 1600 cores of ANTYA for nearly five days of real-time computation for a single run."***

References:

1. *Smolyakov A et al., Phys. Rev. Lett. 89, 125005 (2002).*
2. *J. Chowdhury et al., Phys. Plasmas 16, 082511 (2009).*
3. *G. Merlo et al., Plasma Phys. Control. Fusion 60 (2018).*
4. *Lanti E et al., 2020, Comput. Phys. Commun. 251 107072.*
5. *S. Brunner and J. Vaclavik, Phys. Plasmas 5, 365 (1998).*
6. *R.L. Tanna et al., 2022 Nucl. Fusion 62 042017.*
7. *Tanmay Macwan et al., Nucl. Fusion, 61 (9):096029, Aug 2021.*
8. ***Amit K. Singh** et al., 2023 Nucl. Fusion in press https://doi.org/10.1088/1741-4326/ace06b.*

Simplify Complex HPC Workflows: Introducing Parsl Workflow Tool

In the last article we discussed the importance of workflow tools. **Parsl**, a Python library, is a powerful workflow tool designed to streamline and simplify the execution of tasks in HPC environment. In this article, we explore the key features and benefits of Parsl, and how it can installed and used by HPC users.

Efficient Task Parallelism Users can break down their complex workflows into individual tasks that can be executed concurrently on multiple compute nodes, leveraging Parsl's automatic management of data dependencies among tasks.	***Fault Tolerance and Reliability*** In HPC environment, failures are inevitable and any workflow tool should use fault tolerance mechanisms. Parsl can automatically retry the task or reschedule it on a different compute node if a task fails due to errors or node failure.
Resource Management With its ability to pack tasks efficiently into batch jobs, Parsl can dynamically allocate tasks across compute nodes, ensuring that multiple tasks are executed simultaneously, reducing the time required to complete the analysis.	***Scalability for Large-Scale Workloads*** Whether it's data analysis, simulations, or machine learning tasks, Parsl can efficiently scale up to thousands of tasks, distributing the workload across available compute nodes.

How to Install Parsl on ANTYA?

Parsl can be easily installed using pip or conda, making it accessible to users without the need for additional resources or complex setup procedures. Its lightweight and compatibility with existing Python environments make it a convenient choice for integrating workflow management capabilities into HPC.

```
# First load a conda base module.
[user@login1 ~]$ module load miniconda/3

# Create a conda environment with the name parsl and activate it.
[user@login1 ~]$ conda create --name parsl
[user@login1 ~]$ conda activate parsl
(parsl) [user@login1 ~]$

# Install parsl with pip
(parsl)[user@login1 ~]$ pip3 install parsl

# To check the installed version of parsl
(parsl) [user@login1 ~]$ conda list | grep parsl
# packages in environment at /home/user/.conda/envs/parsl:
parsl        2023.5.29        pypi_0        pypi
```

How Parsl can be used on ANTYA?

Various examples of Parsl are available online to learn how it can be used as a workflow. You may refer the link for comprehensive examples and use cases of Parsl. Here are the steps that one needs to follow:

- ⇒ Install Parsl
- ⇒ Configure Parsl: This may require writing a config file for PBS Pro.
- ⇒ Define your Workflow
- ⇒ Submit Batch Jobs

The configuration with PBS Pro along with an example of Parsl will be covered in the next issue.

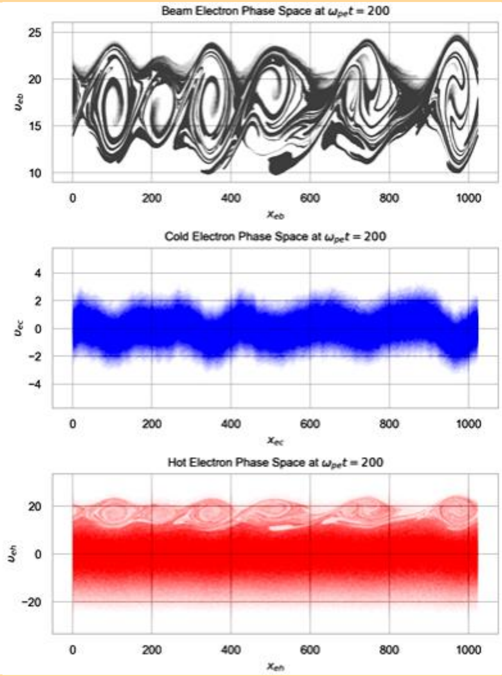
ANTYA UPDATES AND NEWS

1. New Packages/Applications Installed

- ⇒ **Wine**
  wine/7.2
- ⇒ **Pastix**
  pastix/pastix-master

HPC PICTURE OF THE MONTH

Phase Space of an Interacting Three Electron System



Pic Credit: **Rakesh Moulick**

In the ionospheric plasma, interaction of a beam of electrons with the residual hot and cold electron populations give rise to the streaming instability. The figure shows the individual phase spaces of the beam, cold and hot electrons respectively at the onset of the instability. The phase space of the hot electrons show the formation of vortices similar to the beam electrons. After saturation of the instability, the beam electrons form electron holes or solitary wave structures in the phase space.

(submitted for publication, under review link)

The simulation has been performed using Particle-In-Cell serial code and post processing of data is done via Python. A single run took ~ 3 days.

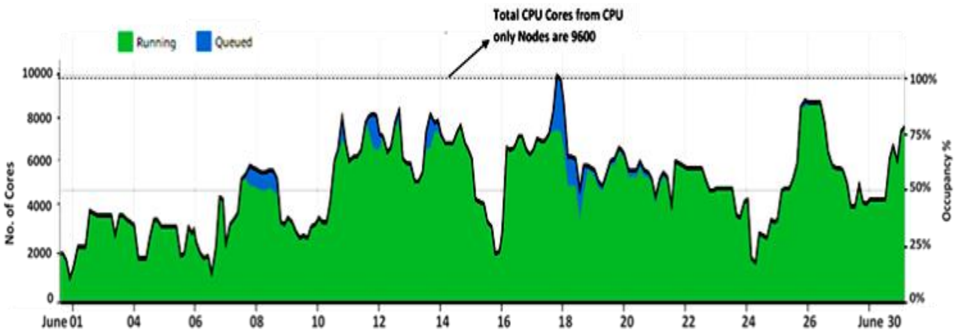
TIP OF THE MONTH

Syncing two directories' content locally at different locations: If you need to sync the content of a directory in your home to a directory in your scratch area, use the following command for incremental sync:

```
[user@login1 ~]$ rsync -avz /home/user/source_directory/ /scratch/scratch_run/user/destination_directory/
```

ANTYA Utilization: JUNE 2023

ANTYA Daily Observed Workload



ANTYA HPC USERS' STATISTICS— JUNE 2023

- **Total Successful Jobs — 7684**
- **Top Users** (Cumulative Resources):

- **CPU Cores** — **Suruj Kalita**
- **GPU Cards** — **Suruj Kalita**
- **Walltime** — **Someswar Dutta**
- **Jobs** — **Someswar Dutta**

Other Recent Work on HPC (Available in IPR Library)

Active Yukawa particles' dynamics over time dependent asymmetric barriers in the "weak interaction" limit	Anshika Chugh
A Staged Approach to Indian DEMO	Shishir P. Deshpande
Particle-In-Cell Simulation of Electrostatic Waves in the Ionosphere	Rakesh Moulick
Computational Fluid Dynamics Simulations for the Gasification of Pulverized Coal Particles in Plasma Fuel System	Sunil Bassi
A weakly relativistic electron beam from laser-cluster interaction in an ambient magnetic field	Kalyani Swain
Numerical Simulation of an Expanding Magnetic Field Plasma using Cylindrical 2D3V PIC-MCC Code	Vinod Saini
Magneto-convective fluctuations in MHD duct flow of electrically conducting fluid in transverse magnetic field	Srikanta Sahu
Spontaneous Fluctuations of Densities in Strongly Coupled Complex Plasma	Ankit Dhaka
Low temperature EXB Plasma simulation in the context of negative ion sources: 2D-3V PIC-MCC model	Miral Ashokkumar Shah
Driven Dynamics of electron plasma waves in the presence of inhomogeneous kinetic ions	Sanjeev Kumar Pandey
MHD प्रेशर ड्रॉप पर इलेक्ट्रिकल इंसुलेशन का प्रभाव	Anita Patel
Development and Testing of a Pneumatic Mechanical Punch for Application in Cryogenic Pellet Injection	Pareshkumar Panchal
Design and Analysis of Cryopump with Opening of 1250 mm	Hemang S. Agravat
Investigation of Toroidal Electron Plasmas: A 3D3V Particle-in-Cell Study Using OpenACC Parallelized PEC3PIC Code	Swapnali Khamaru
Ion-driven destabilization of electron cloud dynamics: A 3D3V Particle-in-Cell study	Swapnali Khamaru
3D Molecular Dynamics Simulation of Dust Charge Dynamics in a Coulomb Screened Plasmas	Suruj Jyoti Kalita
Conceptual design requirements for HCSB blanket for a moderate sized tokamak pilot plant	Piyush Prajapati
Short-pulse laser-cluster interaction in an ambient magnetic field	Mrityunjay Kundu
Investigation of electron plasma waves in the presence of inhomogeneous immobile ions : A fluid and kinetic simulation study	Sanjeev Kumar Pandey
Trapping of wave in a flowing dusty plasma	Krishan Kumar

Acknowledgement

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

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 GAṆANAM, please write to us.

Contact us

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