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(3 Pages)

MAGNETIC SHAPING EFFECTS ON TURBULENCE IN ADITYA-U TOKAMAK

Amit K. Singh (SO-E, ITER-India, IPR)

Email: amitks@ipr.res.in

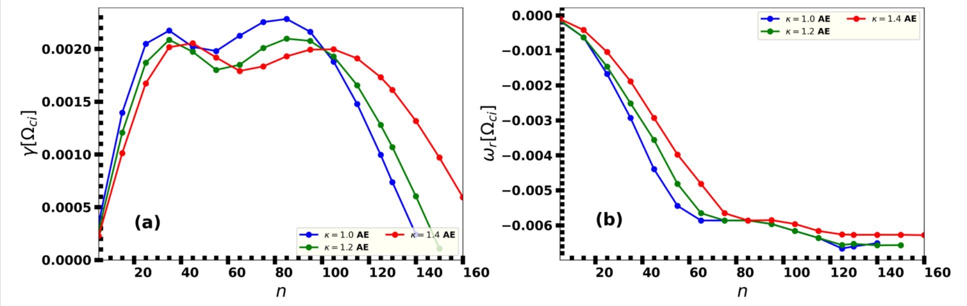

Figure 1: (a) Growth rate (γ/Ω_{ci}) and (b) frequency (ω_r/Ω_{ci}) as a function of the toroidal mode number n for circular (blue), κ = 1.2, δ = 0.45 (green) and κ = 1.4, δ = 0.45 (red) MHD equilibria

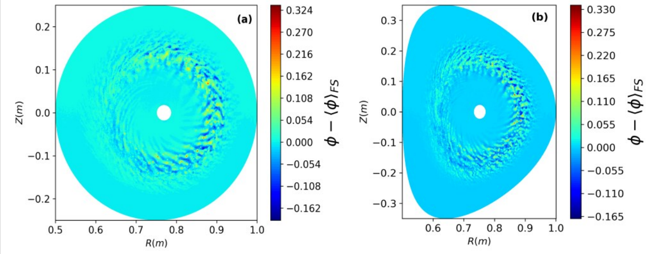

Figure 2: 2D poloidal mode structure of the turbulence for the (a) circular and (b) κ = 1.4 equilibrium at the final time point in simulations.

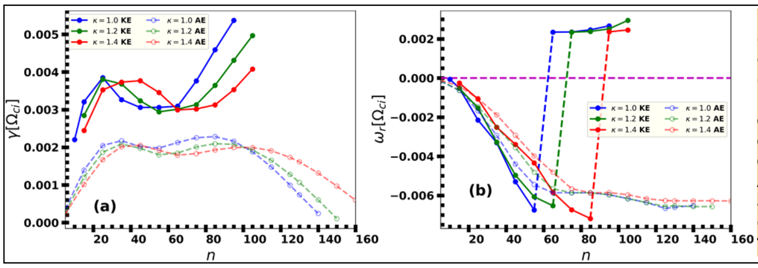

Figure 3: (a) Growth rate (γ) and (b) Real frequency (ω_r) plots for circular (κ = 1.0) and shaped (κ = 1.2 & κ = 1.4) magnetic equilibria for adiabatic electron (AE) and kinetic electron (KE) cases. The AE cases (also Figure 1) are shown with open circles and dashed lines for comparison.

Turbulence in tokamaks, leading to anomalous transport, is thought to arise from various micro-instabilities [1, 2, 3]. In low plasma beta conditions, these instabilities, mainly electrostatic in nature, include Ion Temperature Gradient (ITG), Trapped Electron Modes (TEM), and Electron Temperature Gradient (ETG) modes. The presence of mean density and temperature gradients in magnetically confined plasmas supply the required free energy for these micro-instabilities. For instance, even when $k_\theta\rho_s > 1.0$, the ITG mode, triggered by ion temperature gradients, becomes unstable in the presence of sharply defined background gradients, giving rise to short wavelength ion temperature gradient modes (SWITGs) [4, 5, 6]. Therefore, comprehending the linear and nonlinear properties of these modes and their role in anomalous energy and particle transport is crucial.

The ADITYA-U, a medium-sized Tokamak [7], is well-suited for studying micro-instabilities amidst sharp density and temperature gradients. Recent gyrokinetic simulations [8], using ORB5 [9] with non-adiabatic ions and adiabatic electrons, reveal the coexistence of SWITG mode with the conventional ITG mode in ADITYA-U due to sharp temperature and density gradients. However, in plasmas confined by inhomogeneous magnetic fields, some electrons get trapped in low magnetic field regions. These trapped electrons can enhance micro-instabilities from ion dynamics, such as the ITG-TEM (ITG coupled with trapped electron mode). Moreover, shaped plasma operation in the ADITYA-U tokamak, resulting in the shaping of magnetic equilibrium, could have a substantial impact on the ITG-SWITG branch. Numerical simulations using local delta-f gyrokinetic (GK) codes and analytical equilibrium models indicate that larger elongations and higher triangularity (at high elongations) have a stabilizing effect on ITG-ae (ITG with adiabatic electron) and ITG-TEMs. Global codes also suggest that plasma shaping effects, such as elongation, triangularity, and Shafranov shift, have long been recognized as crucial factors in enhancing tokamak performance. Shaping effects can regulate the ITG turbulence level through zonal flow.

The work reported in this article addresses two aspects. In the first part, numerical simulations are conducted to examine the impact of magnetic equilibrium shaping (elongation and triangularity), on both conventional Ion Temperature Gradient (ITG) modes and Short Wave-length Ion Temperature Gradient (SWITG) modes. This analysis is performed considering the experimental profiles and parameters of the ADITYA-U tokamak, employing the nonlinear global gyrokinetic Particle-in-Cell (PIC) code ORB5 with a real MHD equilibrium obtained from CHEASE code [10]. The linear and nonlinear collisionless electrostatic simulation of these modes are carried out with kinetic ions and adiabatic electrons. From the linear results as shown in Figure 1, it has been observed that the magnetic equilibrium shaping slighty reduced the growth rates and widened the spectrum, and the maxima of growth rate curve is shifted to higher toroidal wave number.

From the nonlinear simulations of ITG-SWITG modes, we find that the heat flux is reduced by a significant ≃ 35% for the true circular MHD magnetic equilibrium as compared to adhoc concentric circular equilibrium reported in [8]. A further ≃ 10% reduction in the heat flux is seen with magnetic equilibrium shaping. Plots of the electrostatic turbulent potential $\tilde{\phi} = \phi - \langle\phi\rangle_{FS}$ at $t = 2.0 \times 10^5\ \Omega_{ci}^{-1}$, (where $\langle\phi\rangle_{FS}$ is the flux surface averaged potential) during the nonlinear simulations for circular and shaped magnetic equilibrium (κ = 1.4) are shown in Figures 2a and 2b respectively. As we can see from Figures 2a and 2b, the zonal flow shear tears the global structures to regulate the turbulence for both the cases. Hence, it is crucial to thoroughly examine the impact of the zonal flow shearing rate.

In the second part, linear collisionless electrostatic simulation studies of ITG coupled with fully kinetic electrons (both trapped and passing electrons are treated kinetically) using a drift-kinetic ordering is performed. It can be seen from the linear results, shown in Figure 3, in presence of kinetic electrons, the growth rate and real frequency of the ITG mode are increased significantly for ADITYA-U parameters and a mode propagating in the electron diamagnetic direction at high toroidal wavenumbers. For our present parameters and profiles, this is the TEM, but a proper treatment of collisions, for example, is necessary to characterise the mode. The detailed results of present work are availble in the published work [11].

The linear and nonlinear simulations conducted in this study extensively utilized the computational resources of the ANTYA cluster at IPR to model micro-turbulent transport phenomena in the ADITYA-U tokamak. Specifically, for the linear simulations, a total of 60 individual runs were executed, each requiring 72 CPU hours and utilizing 1024 cores per run. The cumulative time required to complete all linear simulations was approximately three months. In contrast, for the nonlinear simulations, three separate runs were performed, each employing 1600 cores and necessitating 192 CPU hours per run. The cumulative time required to complete all nonlinear simulations was approximately one months.

References:

[1] G. Rewoldt, W.M. Tang Phys. Fluids B 2 (1990) 318–323.
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[3] F. Merz, F. Jenko Nucl. Fusion 50 (2010) 054005.
[4] Smolyakov A et al Phys. Rev. Lett. 89, 125005 (2002).
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[8] Amit K. Singh et al 2023 Nucl. Fusion 63 086029.
[9] Lanti E et al Comput. Phys. Commun. 251 107072, 2020.
[10] H. Lütjens et al Comput. Phys. Commun. 97 (1996) 219.
[11] Amit K. Singh et al 2024 Nucl. Fusion 64 106005. DOI: 10.1088/1741-4326/ad6b36

Isolate and Organize: A Comprehensive Guide to Spack Environment Management

Spack is a versatile and powerful package manager tailored for high-performance computing (HPC) and scientific research environments. It streamlines the process of building, installing, and managing software, allowing users to easily handle complex software stacks with multiple dependencies. A detailed introduction to and configuration of spack in user environment has been covered in HPC Newsletter Issue 29 and 30 .

This article will cover about spack environments just like conda environments. Spack environments provide isolated, reproducible software stacks, allowing users to manage and organize complex dependencies in a controlled setting. They simplify switching between different project configurations and ensure consistency across different systems and workflows.

Refer below steps to configure spack environment and how to use it. (Refer above mentioned articles to install and configure spack in users' environment)

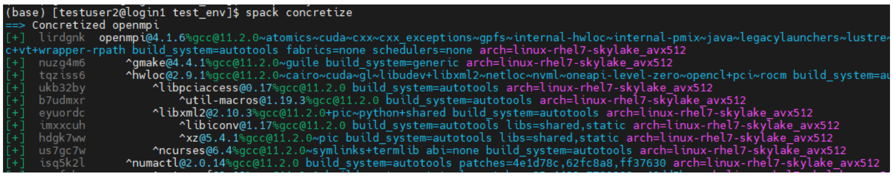
A) Create and Activate New Environment in Spack

```
[testuser2@login1 ~]$ spack env create test_env
==> Created environment 'test_env' in /home/testuser2/spack/var/spack/
environments/test_env
==> You can activate this environment with:
==> spack env activate test_env

[testuser2@login1 ~]$ spack env activate test_env
```

B)Specify Package in the environment

```
[testuser2@login1 ~]$ vi home/testuser2/spack/var/spack/environments/
test_env/spack.yaml
//Add below packages which user wants to install in spec part of the file.

spack:
  # add package specs to the `specs` list
  specs:
  - openmpi
  view: true
  concretizer:
    unify: true
```

C) Concretize and Install the packages

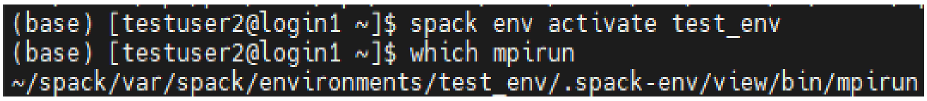


```
(base) [testuser2@login1 test_env]$ spack concretize
==> Concretized openmpi
[+]  lirdgnk  openmpi@4.1.6%gcc@11.2.0~atomics~cuda~cxx~cxx_exceptions~gpfs~internal-hwloc~internal-pmix~java~legacylaunchers~lustre~
c+vt+wrapper-rpath build_system=autotools fabrics=none schedulers=none arch=linux-rhel7-skylake_avx512
[+]  nuzg4m6      ^gmake@4.4.1%gcc@11.2.0~guile build_system=generic arch=linux-rhel7-skylake_avx512
[+]  tqziss6      ^hwloc@2.9.1%gcc@11.2.0~cairo~cuda~gl~libudev+libxml2~netloc~nvml~oneapi-level-zero~opencl+pci~rocm build_system=au
[+]  ukb32by          ^libpciaccess@0.17%gcc@11.2.0 build_system=autotools arch=linux-rhel7-skylake_avx512
[+]  b7udmxr              ^util-macros@1.19.3%gcc@11.2.0 build_system=autotools arch=linux-rhel7-skylake_avx512
[+]  eyuordc          ^libxml2@2.10.3%gcc@11.2.0+pic~python+shared build_system=autotools arch=linux-rhel7-skylake_avx512
[+]  imxxcuh              ^libiconv@1.17%gcc@11.2.0 build_system=autotools libs=shared,static arch=linux-rhel7-skylake_avx512
[+]  hdgk7ww              ^xz@5.4.1%gcc@11.2.0~pic build_system=autotools libs=shared,static arch=linux-rhel7-skylake_avx512
[+]  us7gc7w          ^ncurses@6.4%gcc@11.2.0~symlinks+termlib abi=none build_system=autotools arch=linux-rhel7-skylake_avx512
[+]  isq5k2l      ^numactl@2.0.14%gcc@11.2.0 build_system=autotools patches=4e1d78c,62fc8a8,ff37630 arch=linux-rhel7-skylake_avx512
```

```
[testuser2@login1 ~]$ spack install
// This will install all the dependencies within the spack environment
```

D) Load and Use the environment

```
[testuser2@login1 ~]$ . spack/share/spack/setrup-env.sh

[testuser2@login1 ~]$ spack env activate test_env
//All packages will be isolated from the base environment, user may change
spack.yaml file and update the packages as necessary and redo step 3.
```



```
(base) [testuser2@login1 ~]$ spack env activate test_env
(base) [testuser2@login1 ~]$ which mpirun
~/spack/var/spack/environments/test_env/.spack-env/view/bin/mpirun
```

E) Deactivate the environment

```
[testuser2@login1 ~]$ spack env deactivate
// This will deactivate the spack environment.
```

ANTYA UPDATES AND NEWS

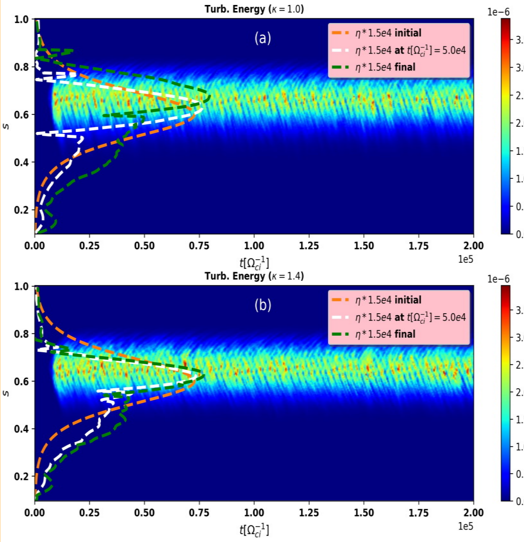
1. New Packages/ Applications Installed

=> A new Module named pigz has been installed

module load pigz-2.8

To check the list of available modules
$ module avail –l

HPC PICTURE OF THE MONTH



Pic Credit: Amit Singh

Spatio-temporal contour plots of the turbulent energy (non-zonal component of electrostatic field energy) for ADITYA-U parameters, separately for the circular (top panel) and shaped (κ = 1.4)(bottom panel) cases. Also shown are the radial plot of $\eta = L_n/L_T$ at initial (orange dashed line), at $t[\Omega_{ci}^{-1}] = 5.0 \times 10^4$ (white dashed line) and final (green dashed line) times. The factor 1.5×10^4 is multiplied in the η profile for visibility

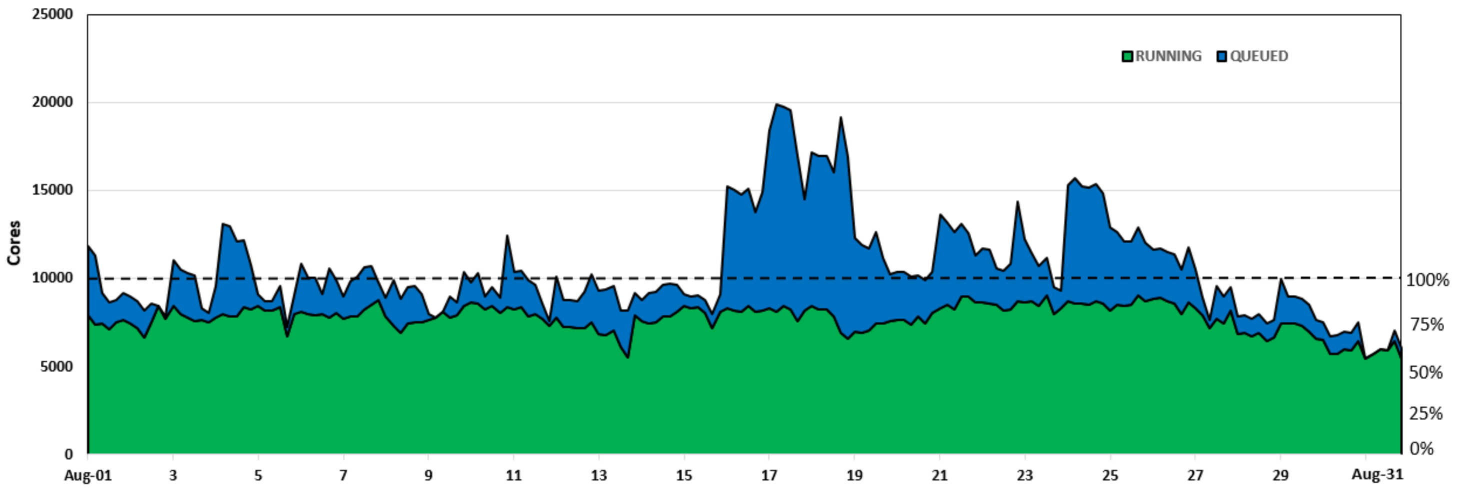
Adding Packages in spack environment using command line

After activating the environment, instead of adding packages in spack.yaml file, user may use below command to add packages directly.

```
[user@login1]$ spack add openmpi
[user@login1]$ spack add lammps
[user@login1]$ spack concretize
[user@login1]$ spack install
```

ANTYA Utilization: AUGUST 2024

ANTYA Daily Observed Workload



Other Recent Work on HPC

The Cryopump AGASTYA: A step towards Self Reliance	**Ranjana Gangradey**
Merging dynamics of plasma blobs in the Scrape-off Layer of a tokamak	**Souvik Mondal**
Development of Mach Probe for the Ion flow measurement in the Helicon Plasma Thruster system	**Mariammal M**
Interaction of driven “cold” electron plasma wave with thermal bulk via ion spatial inhomogeneity	**Rajaraman Ganesh**

ANTYA HPC USERS’ STATISTICS— AUGUST 2024

Total Successful Jobs~ 1227

• **CPU Cores**	**Amit Singh**
• **GPU Cards**	**Suruj Kalita**
• **Walltime**	**Amit Singh**
• **Jobs**	**Amit Singh**

Acknowledgement

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