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HIGH PERFORMANCE *COMPUTING* NEWSLETTER

INSTITUTE FOR PLASMA RESEARCH, INDIA

INSIDE THIS ISSUE

(3 Pages)

Theory of Plasma Blob Formation and its Numerical and Experimental Validations

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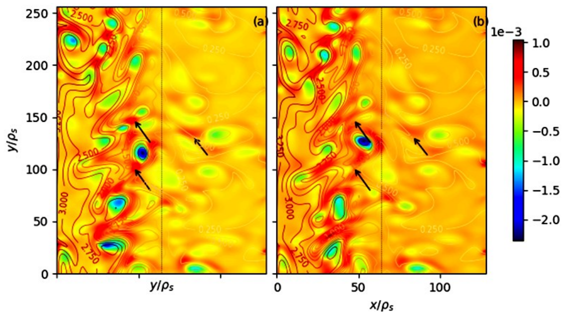


Figure 1: Plasma blob formation from Q factor, (a) and (b) indicate before and after blob formation. The magnitude of Q is shown in the color bar. The position of blob formation is shown by arrows. Plasma blobs have negative Q and unstable positions have positive Q.

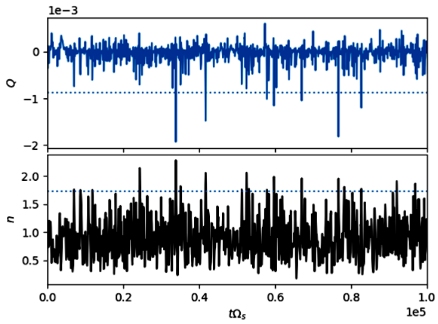


Figure 2: Blob tracking using the peaks of Q-factor and plasma density when they exceed 4 times of the standard deviation as indicated by two horizontal dotted lines. All magnitudes are in normalized units.

Plasma 'blobs' are localized enhanced density structures that have been widely observed in the linear and turbulent edge and scrape-off layer (SOL) regions of several tokamaks/stellarators. They are believed to contribute to the anomalous transport observed in these devices that degrade the plasma confinement and become a threat to the plasma-facing materials, as the anomalous transport leads to enormously high heat and particle loads that may burn the plasma-facing materials. Therefore, these blob structures have been studied extensively in recent years so that the plasma-facing materials can be operated safely. While a great deal of theoretical and experimental work has been devoted to characterizing plasma blobs and their dynamics, the topic of mechanisms underlying the formation of blobs has received limited attention. Systematic and concerted efforts have been made at the Institute for Plasma Research (IPR) for developing a generalized analytical criterion for plasma blob formation. The validity of the theoretical criterion against numerical simulations and experimental data is done. We have tested the facts of the theoretical work including some comparisons with experimental data from various machines like TORPEX (EU), NSTX (USA) and ADITYA devices (INDIA).

> ***"Electric field shears create plasma blobs that deteriorates plasma confinement in a fusion-grade plasma, as validated by our numerical simulations and experimental data."***

Plasma turbulence in plasma's edge and SOL regions has been described by electron, current, and electron energy conservation equations [1-4]. These equations have been solved numerically in the turbulent saturated phase using BOUT++ framework code jointly developed by the University of York (UK), LLNL, CCFE, DTU, and other international partners. The code uses Finite-difference with a variety of numerical methods, and time-integration solvers that are quite modular, enabling fast testing of equations where these equations appear in a readable form. We have used these equations in three-dimensional (3D) and two-dimensional (2D) forms with 256x256x32 and 256x256 grids resolutions, respectively. The time integration of the equations for 3D and 2D cases has been done using the adaptive time-stepping method. The visualization of the numerical data has been done using python3-matplotlib package and the data analysis has been done using python3-numpy, and python3-scipy packages. We have used *ANTYA* HPC cluster in IPR for MPI runs using 128 cores for 3D, and 32 cores for 2D numerical simulations.

The plasma blob formation has been found from a density structure that is radially elongated and poloidally finite, and has a plasma density much higher than the background. This type of structure is called a streamer structure, the plasma blob forms from the breaking of these streamer structures. These structures break under the action of differential shear, such that the total shear rate is much higher than the growth rate. A theoretical criterion has been developed using Taylor expansion method where these stress and growth rates have been used. Using a 3D numerical simulation, we have proved this theory of breaking [3]. It is found that electron temperature plays an important role that makes the plasma vorticity into monopolar vorticity. Numerically, the blob formation has been demonstrated using 2D simulations [1-2,5]. It has been shown that some types of blob formation are only possible through the existence of the electron temperature gradient. Using a different approach, we have also demonstrated the plasma blob formation, where we have calculated the Q factor using these stresses and plasma vorticity [4]. Q factor is positive if the sum of the square of these stresses exceeds the square of the vorticity and negative otherwise. It is demonstrated that the plasma blob forms if a part of the streamer structure has a positive square root of Q that is higher than the growth rate. The Figure-1(a)-(b) shows the formation of a plasma blob structure from a radially elongated streamer. Q-factor has also been used to identify/track plasma blobs. It is found that the existence of a plasma blob is related to the negative value of Q. Therefore, using the same Q-factor, we have demonstrated the plasma blob formation and also plasma blob tracking as shown in Figure-2. Using gas-puff imaging, and arrays of Langmuir probes the plasma blob formation has also been validated experimentally in NSTX and Aditya tokamaks [5].

References:

1. ***N. BISAI,*** *DAS, A., DESHPANDE, S., et al., Formation of a density blob and its dynamics in the edge and the scrape-off layer of a tokamak plasma. Physics of Plasmas, 12 10 (2005) 102515.*
2. ***N. BISAI,*** *SANTANU BANERJEE, A. SEN, A universal mechanism for plasma blob formation. Physics of Plasmas, 26 2 (2019) 020701.*
3. *VIJAY SHANKAR, N. BISAI, SHRISH RAJ, A. SEN, Finite electron temperature gradient effects on blob formation in the scrape-o layer of a tokamak plasma." Nuclear Fusion, 61 6 (2021) 066008.*
4. ***N. BISAI,*** *SANTANU BANERJEE, S. J. ZWEBEN, and A. SEN, Experimental validation of universal plasma blob formation mechanism. Nuclear Fusion, 62 2 (2022) 026027.*
5. ***N. BISAI,*** *and A. SEN, Blob tracking and formation in edge and SOL plasmas using Q-factor, Plasma Phys. Control. Fusion 64 (2022) 115011.*

Simplifying Package Management in HPC Environment with Spack on ANTYA

This article introduces Spack, a package management tool designed for the HPC environment. It enables administrators as well as users to easily install, build, and maintain a wide range of software packages and libraries. For more details, you may check the GitHub link (click here).

What is Spack?

Spack is a powerful and flexible open source tool that can simplify the process of installing, managing, and building software packages in HPC environments.

> ***"Spack can simplify the process by automatically resolving dependencies and ensuring that all required packages are installed correctly."***

> ***"Spack provides a flexible and customizable build system that allows choosing different compiling options to build custom applications."***

When to Use Spack?

Spack can be useful for installing multiple versions of the same package having a complex set of dependencies. It also provides a variety of build options, which allow users to customize the installation process to their specific needs while resolving the dependencies in the background.

How to Use on ANTYA?

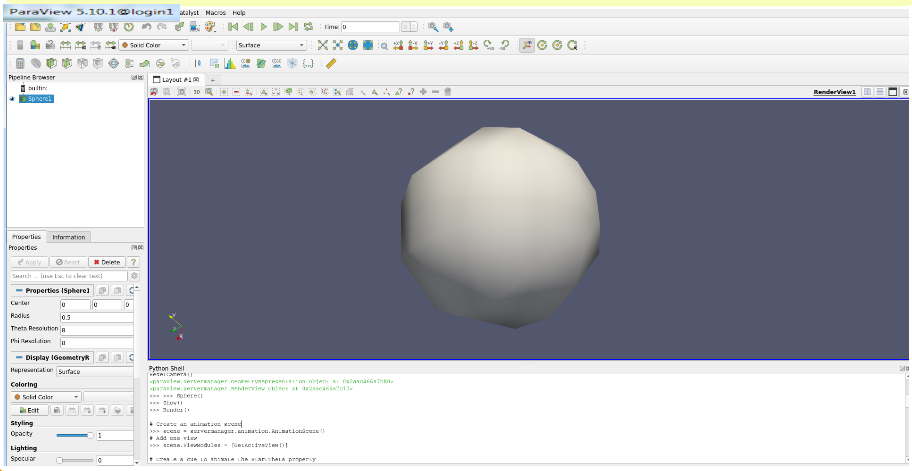
On ANTYA, Spack has been made available at a shared location and can be easily loaded in the user environment. Here we will demonstrate how Paraview-5.10.1 installed using Spack at shared location on ANTYA, can be easily obtained by users for their use.

```
# Accessing Spack
[user@login1 ~]$ module load Spack/spack
[user@login1 ~]$ source /home/application/spack19/spack/share/spack/setup-env.sh
[user@login1 ~]$ spack compiler add

# Checking if the required package Paraview is installed or not using Spack
[user@login1 ~]$ spack find paraview
-- linux-rhel7-skylake_avx512 / gcc@11.2.0 --------------
paraview@5.10.1
==> 1 installed package

# Loading the Spack installed package Paraview
[user@login1 ~]$ spack load paraview@5.10.1

# Launching Paraview, make sure you have enabled –X for graphics.
[user@login1 ~]$ paraview
```



ANTYA UPDATES AND NEWS

1. New Packages/Applications Installed

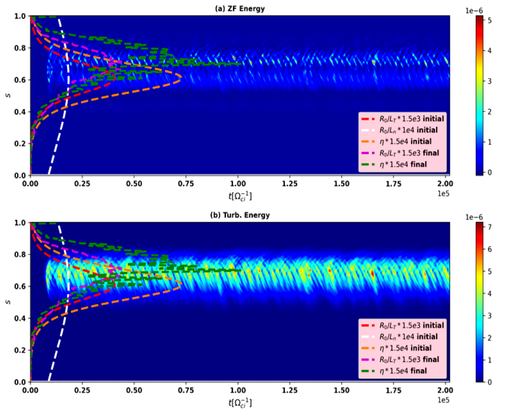
⇒ **GCC-11.2.0**
module load gcc/11.2.0

⇒ **RUPTURA code**
module load RUPTURA/rupture

⇒ **Spack package manager**
sh /home/application/spack/spack/share/spack/setup-env.sh

HPC PICTURE OF THE MONTH

Spatio-temporal contour plots of the electrostatic field energy



Pic Credit: **Amit Singh**

The figure shows spatio-temporal contour plots of the electrostatic field energy using, separately for the zonal (top panel) and non-zonal (bottom panel) components. Also shown are the radial plots of R_0/L_T at initial (red dashed line) and final (magenta dashed line) time, R_0/L_n (white dashed line) at initial time and eta = L_n/L_T at initial (orange dashed line) and final (green dashed line) time.

[Ref: Gyrokinetic simulation of multi-scale ion temperature gradient instabilities in the ADITYA-U Tokamak, Amit K. Singh et al, Nucl. Fusion, under review (2023)]

The above figure has been created with the data obtained from ORB5 (a nonlinear global gyrokinetic PIC code) simulation using 1.5 billion particles that took around 120 hours on 1536 cores of ANTYA.

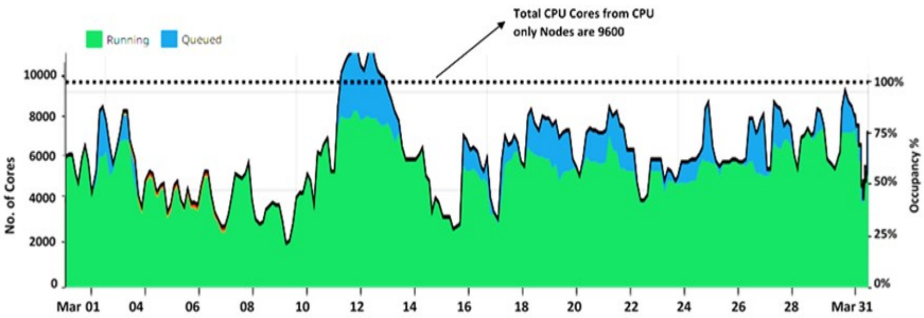
TIP OF THE MONTH

To optimize your code for performance, it is important to take advantage of the vector processing capabilities of modern processors on ANTYA nodes. One simple approach is to use "-xHost" flag during compilation.

```
# An example to enable vectorization in a C program, test.c, with Intel compiler.
[user@login1 ~]$ icc -O3 -xHost -fopenmp test.c -o test
```

ANTYA Utilization: MARCH 2023

ANTYA Daily Observed Workload



ANTYA HPC USERS' STATISTICS— MARCH 2023

♦ **Total Successful Jobs — 2124**

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

- **CPU Cores** Amit Singh
- **GPU Cards** Shishir Biswas
- **Walltime** Sneha Gupta
- **Jobs** Someswar Dutta

Other Recent Work on HPC (Available in IPR Library)

Physics and Engineering Considerations for Compact Fusion Pilot Plants	Piyush Prajapati
Conceptual Design of a Moderate Sized Fusion Pilot Plant	Piyush Prajapati
Design of Solid Breeder Blanket using mixed bed of Li2TiO3 and Be12Ti	Deepak Sharma
SARAS: A WORKFLOW-BASED MULTI-PHYSICS SIMULATOR FOR TOKAMAK PHYSICS AND REACTOR DESIGN	Shishir P. Deshpande
RUNAWAY SIMULATION IN ADITYA-U TOKAMAK PARAMETER REGIME USING VLASOV MAXWELL MODEL	Anjan Kumar Paul
Soft Active particles in confined geometries	Anshika Chugh
Assessment of stacked LSTM, Bidirectional LSTM, ConvLSTM2D and Auto encoders LSTM time series regression analysis at Aditya-U tokamak	Rameshkumar Joshi
Computer Execution and Functional Validation of BRAC code	Akshaya Kumar Shaw
A STAGED APPROACH TO INDIAN DEMO AND TECHNOLOGY ROADMAP	Shishir P. Deshpande
EMC3-EIRENE SIMULATIONS OF MAIN CHAMBER RECYLING ON ITER	Arzoo Malwal
SIMULATIONS OF INBOARD LIMITED SCRAPE OFF LAYER PLASMA OPERATIONS IN ADITYA-UPGRADE TOKAMAK	Arzoo Malwal
SIMULATIONS OF UNMITIGATED AND MITIGATED ITER DISRUPTIONS WITH IMPROVED HALO MODEL IN TSC	Indranil Bandyopadhyay
EXPERIMENTAL AND SIMULATION STUDY ON ARCING INCIDENCES OF SST-1 PF3 VACUUM BARRIERS AND MITIGATION TECHNIQUES	Swati Roy
PHYSICS OF PLASMA BLOB FORMATION AND EXPERIMENTAL VALIDATION	Nirmal K. Bisai
CONTROL OF EDGE AND SOL PLASMA TURBULENCE USING IMPURITY SEEDING AND EXTERNAL BIAS	Nirmal K. Bisai
200 kW, 1 MHz DUAL DIRECTIONAL COUPLER: DESIGN AND CHARACTERIZATION	Akhil Jha
R&D for the development of compact HTS coils	Mahesh M Ghate
GLOBAL GYROKINETIC SIMULATION OF ELECTROSTATIC MICROTURBULENT TRANSPORT IN ADITYA-U	Joydeep Ghosh
Effect of flow shear on the onset of dynamos	Shishir Biswas
ITG-TEM turbulence simulation for ADITYA-U Tokamak	Amit Kumar Singh
DISRUPTION PREDICTION ON ADITYA-U USING FUTURE SEQUENCE BASED TIME SERIES NEURAL NETWORK	Rameshkumar Joshi
DESIGN DEVELOPMENT OF DRIFT DUCT FOR DIAGNOSTIC NEUTRAL BEAM SYSTEM OF ITER	M. Venkata Nagaraju
TOKAMAK TRANSPORT UNDER FLAT TEMPERATURE SCENARIOS USING GLOABAL GYRO-KINETIC SIMULATIONS	Sagar Choudhary

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.***

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If you wish to contribute an article in GAṆANAM, please write to us.

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