GA-Theory Collaboration with NSTX-U

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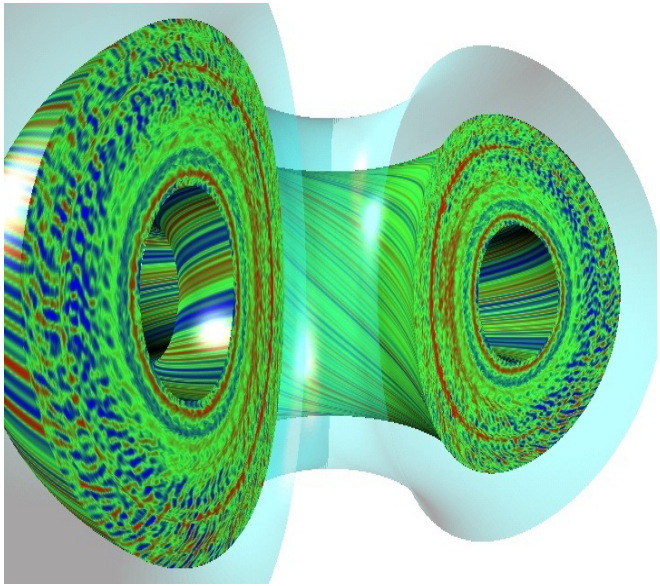

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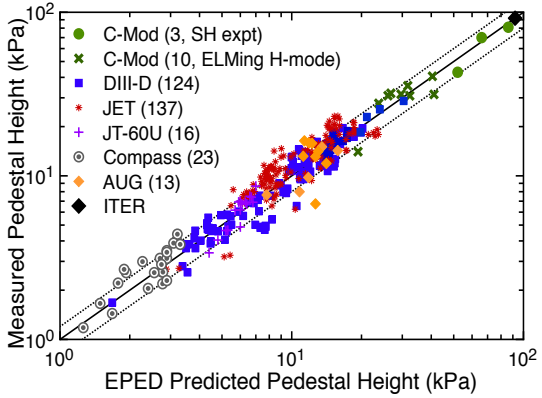
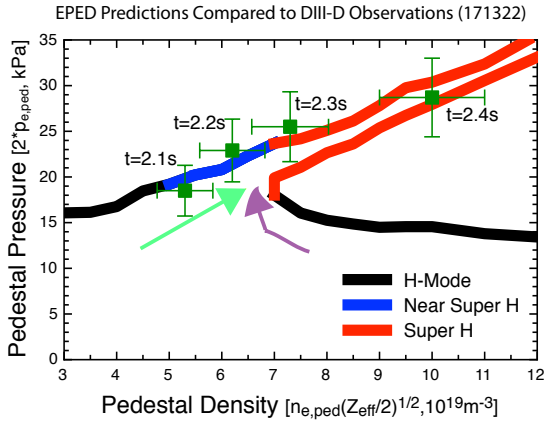
GA-Theory partnership with DIII-D experimental science

- Since the beginning of General Atomics in the 1950's there has been a theory department that proposed the doublet concept and partnered in the experimental validation of physics models
- GA-Theory has been a productive partner in defining and achieving the goals of the DIII-D experimental program since 1987
- The GA-Theory team will work closely with PPPL and the NSTX-U collaborators to help achieve the NSTX-U 5-year plan goals for physics validation
- The GA-Theory collaboration will hire two ORAU fellows and train them in the art of experimental validation of physics using the suite of codes and methods we have developed
  - These ORAU fellows will work on-site at NSTX-U
- Pedestal stability and gyrokinetic turbulent transport are the areas of focus for this collaboration

A new ELITE code for pedestal stability in low aspect ratio geometry

- The ELITE code predictions of the peeling-ballooning mode stability of H-mode pedestals has been successful in tokamaks
- A new version of ELITE is in development with the higher accuracy required for low aspect ratio geometries like NSTX-U
- Extension of the EPED reduced model for pedestal structure to NSTX-U is a goal of the collaboration

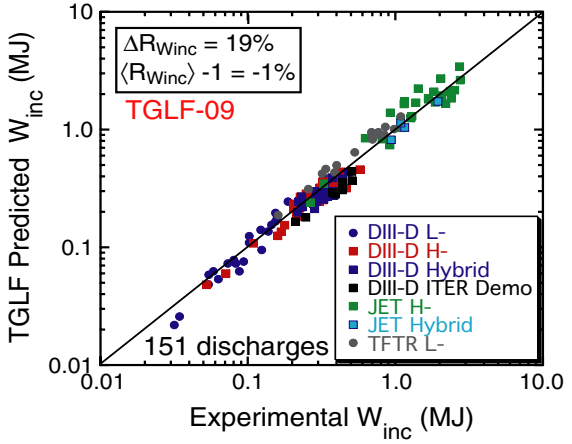


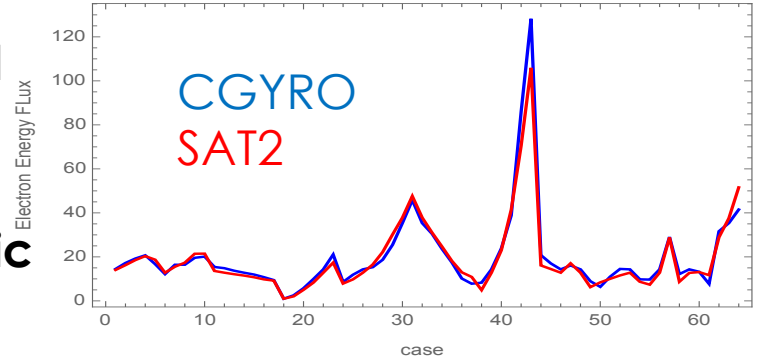


GENERAL ATOMICS

Validation of quasi-linear turbulent transport in NSTX-U

- The quasi-linear approximation to gyrokinetic turbulence has proven to be accurate for tokamaks
- A new SAT2 saturation model has been developed from CGYRO simulations
- The SAT2 model was fit with CGYRO linear eigenmodes (QLGYRO)
- The SAT2 model is designed for the low aspect ratio and high shaping of spherical torus geometry
- A new fast linear eigensolver is being developed to resolve the parallel magnetic field fluctuations better than the TGLF eigensolver

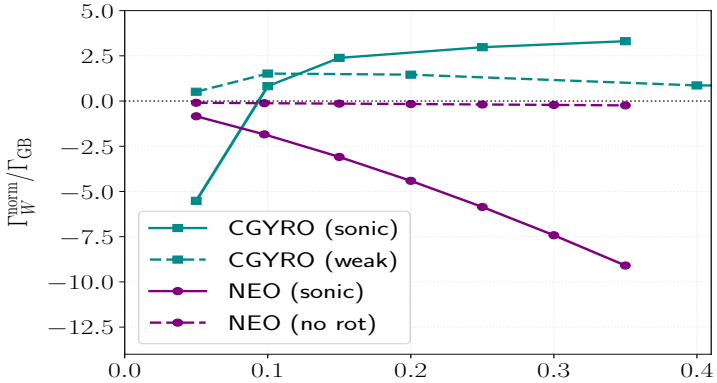


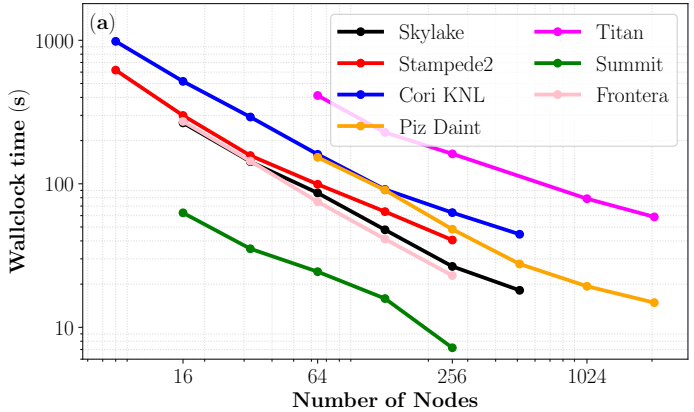


GENERAL ATOMICS

CGYRO and NEO are NSTX-U ready

- The collisional transport code NEO and gyrokinetic code CGYRO have general geometry, high rotation physics, and multi-ion collisions
- The CGYRO gyrokinetic code has been highly optimized for GPU computing for multi-scale turbulence (electron + ion scales)
- A database of CGYRO runs performed for NSTX-U by Walter Guttenfelder will be used to verify the TGLF-SAT2 model as a first project





GENERAL ATOMICS

GA-Theory brings experience to the NSTX-U collaboration

- **Gary Staebler GA-Theory – PI**
  - Developer of the TGLF quasi-linear model for GK turbulent transport
- **Emily Belli GA-Theory**
  - Developer of the NEO collisional transport and CGYRO gyrokinetic turbulence codes
- **Phil Snyder ORNL**
  - Developer of the ELITE edge MHD stability code and the EPED model
- **Jon Kinsey CompX**
  - Expert in large database validation of transport models
  - Contributor to TGLF, and MM95 models
- **Tom Neiser GA-Theory**

Milestones of the collaboration Oct. 2021-2023

- Verify the turbulence intensity of the new SAT2 saturation model with the existing large CGYRO ST turbulence simulation database
- Install the QLGYRO code (SAT2 + CGYRO linear eigenmodes) in the OMFIT STEP workflow for use on a PPPL cluster.
- Validate the micro-tearing mode (MTM) transport predicted with the QLGYRO code against previously identified NSTX discharges that have MTMs
- Install Rafiq MTM model in TGYRO.
- Compare the QLGYRO and Rafiq models for MTM stability and transport.
- Perform CGYRO linear stability and non-linear turbulence analysis of the H-mode barrier region extending the range of analysis already done by NSTX-U staff.
- Build a database of CGYRO calculations of the KBM critical pedestal profile in STs.

Milestones of the collaboration Oct. 2023-2025

- Validate the new ELITE peeling ballooning stability calculations with NSTX-U data
- Investigate the energy confinement scaling with collisionality on NSTX-U with QLGYRO and reduced models TGLF and Rafiq MTM
- Predict with new EPED model if NSTX-U can access the super-H or other enhanced, pedestal regimes
- Investigate the impact of low particle fueling on EPED pedestal structure modeling with Lithium wall conditioning discharges as a proxy for ITER opaque SOL
- Validate the new TGLF with transport modeling of high bootstrap fraction NSTX-U discharges

Postdoctoral Positions in theoretical and computational plasma physics, through Oak Ridge Associated Universities

The gyrokinetic theory of turbulent transport, and the magnetohydrodynamic theory of peeling-ballooning stability, have proven to be accurate physics models of conventional aspect ratio tokamak plasmas. The General Atomics Theory and Computational Science (GA-Theory) division has been awarded a grant to extend the validation of these theories, and reduced models for transport and pedestal structure, to the low aspect ratio geometry of the National Spherical Torus Experiment Upgrade (NSTX-U) operated by the Princeton Plasmas Physics Laboratory (PPPL).

We currently have two exciting opportunities for outstanding candidates to undertake postdoctoral positions onsite at PPPL representing GA-Theory in close collaboration with NSTX-U researchers. Appointments are administered by Oak Ridge Associated Universities (ORAU). The successful candidates will be given training as a theoretical analyst, validating codes developed by GA-Theory for turbulent transport and pedestal structure with existing and new NSTX-U data. A theoretical analyst participates in the planning, execution, and analysis of experiments as a collaborator in the experimental program. In addition, the fidelity of reduced transport models to gyrokinetic turbulence simulations and linear stability will be verified. A validated reduced model for pedestal structure and stability is a shared goal of this grant with the NSTX-U research plan. Two positions, one focused on transport and the other on pedestal structure are open. The training given by GA-Theory scientist will equip the candidate with state-of-the-art gyrokinetic simulation experience with the CGYRO code that is optimized for the exascale computing environment. The candidate will learn the methods used to construct the quasi-linear transport model TGLF and the pedestal structure model EPED from their primary developers. They will also learn to run a new, high resolution, version of the peeling-ballooning code ELITE and a new variable resolution gyro-fluid eigensolver that have been developed for spherical tori. This knowledge, and the experience of working in the exciting collaborative environment of NSTX-U, will build the foundation for a career in fusion energy research. Interested candidates should contact Gary Staebler (staebler@fusion.gat.com).

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