

Featured Application:

Hampton University: Center for Fusion Research & Training's Tokamak Divertor Maps

ABSTRACT: Hampton University's Center for Fusion Research & Training (HU CFRT) research is focused on the development of symplectic mathematical maps called Tokamak Divertor Maps. These maps calculate the trajectories of magnetic field lines in divertor tokamaks such as DIII-D, JET and ITER, which are used in the production of energy via fusion. The maps calculate the stochastic layer and magnetic footprint that result from different kinds of magnetic perturbations. The maps help researchers understand the edge physics in divertor tokamaks, which is crucial to the success of controlled fusion devices such as ITER for the production of fusion energy.

Understanding the Science

Researchers at Hampton University (HU) are contributing to an international effort to provide the world with energy produced from controlled thermonuclear fusion - a safe, clean and sustainable alternative to the current worldwide use of fossil fuels. Magnetic confinement fusion is one method of producing fusion energy. Tokamaks combine two magnetic fields to confine the extremely hot plasma inside a doughnut shaped chamber to produce fusion. Large modern tokamaks have divertors in which the field at the edge is modified to divert the plasma at the edge away from the main plasma. The International Thermonuclear Experimental Reactor (ITER), which is designed as a divertor tokamak, will be the world's largest tokamak. ITER is an international endeavor and is the most ambitious fusion project ever. The ITER is a next-step tokamak in achieving the goal of the commercial production of fusion energy.

The research being done at the HU CFRT increases the understanding of the physics of the plasma in the edge region of divertor tokamaks, which is crucial to their success in creating fusion energy. In order to run a divertor tokamak efficiently, scientists work to limit the destruction of the magnetic surfaces (caused by magnetic perturbations) inside tokamaks. Magnetic surfaces in a divertor tokamak are created by combining two components of magnetic field and constrain the orbiting charged particles in the plasma. Sometimes perturbations to the magnetic surfaces are applied deliberately to control instabilities in the edge. The focus of the HU CFRT's research is the symplectic mathematical maps for calculating the trajectories of a divertor tokamak's magnetic field lines, and the HU CFRT is the world's leading center in this area.

Hampton University's Prof. Alkesh Punjabi and Prof. Allen Boozer of Columbia University have done pioneering work in developing area-preserving maps for divertor tokamaks. Their maps are used in calculating the stochastic layer and the magnetic footprint that result from different kinds

of magnetic perturbations and can help understand and estimate the effects of magnetic perturbations on magnetic surfaces. Magnetic perturbations in a divertor tokamak destroy the symmetry of magnetic surfaces. In divertor tokamaks, the magnetic surfaces in the main plasma region are closed surfaces, while the magnetic surfaces in the edge region are open surfaces. The closed and open surfaces are separated by a special surface called the separatrix surface. The magnetic perturbations destroy the separatrix surface and create a region of chaotic (stochastic) magnetic field lines in the neighborhood of where the separatrix surface existed.

The HU CFRT's mathematical maps preserve the topological invariance of the Hamiltonian system, have the advantage of computational efficiency, and are used to calculate the structure and topology of the stochastic layer and the magnetic footprint in divertor tokamaks as different types of magnetic perturbations are introduced. The Symmetric Simple Map and the Dipole Map are among the maps Profs. Punjabi and Boozer have already developed. Of the new maps that they are currently developing, the DIII-D maps will calculate field line trajectories in the DIII-D tokamak at General Atomics in San Diego - the largest tokamak in the United States.

Application Characteristics

The HU CFRT's symplectic maps are used to calculate the long-term trajectories of a large number of field lines with different initial positions. Since the evolution of each field line is independent of other field lines, each computer processor can be used independently to calculate the path of one field line. Once the paths of all the field lines are calculated, their accumulative statistical behavior can be determined. The HU CFRT's map research is ideally suited to run on a large number of processors in a parallel fashion and the computational resources available on SURAgid can therefore be useful in their research.

SURAgriD Deployment

The HU CFRT team expects to use SURAgriD resources for a number of steps in their maps research, which includes code writing, testing, debugging, parallelization techniques (e.g., OpenMP¹), production, creating graphics (e.g., Tecplot²), plus using symbolic manipulation programs (e.g., MATLAB³, Mathcad⁴) and paper writing software. The HU CFRT's goals and plans are long-term - their work will take a considerable amount of time and they hope to make use of both SURAgriD's compute resources and its growing application deployment support services.

Grid Workflow

Currently, Prof. Punjabi's team is in the early stages of deploying their application on SURAgriD. HU CFRT researchers and graduate students that are working with Prof. Punjabi will be accessing SURAgriD resources in the future. Initially, the team members are gaining access to SURAgriD resources through an affiliate user certificate issued by SURAgriD participant site Georgia State University (GSU). GSU has a Certificate Authority (CA) that has been cross-certified with the SURAgriD Bridge CA (BCA)⁵ and this cross-certification enables SURAgriD resource sites to trust the certificates HU CFRT users will present them. GSU's SURAgriD User Administrator can create SURAgriD accounts for HU CFRT users, which will in effect give the users single-sign-on access to SURAgriD resources at cross-certified SURAgriD sites. SURAgriD is in the process of bringing up a SURAgriD CA for ongoing issuance of user certificates for sites that are not also resource providers in SURAgriD. The SURAgriD CA would also support guest access to SURAgriD, and provide a means of interim coverage for sites that are in the process of bringing up their own CAs.

One of the first steps the team has undertaken is to determine the best way(s) to remotely access SURAgriD resources for their particular users and application. Jobs on SURAgriD can be submitted through the SURAgriD portal or the command-line, and Prof. Punjabi is assessing SSH client software for the latter method. Once that assessment is completed, Prof. Punjabi's team will begin modifying their application code so that it can take the best advantage of SURAgriD resources. Some of the aspects of grid-enabling the application software the HU CFRT team may consider as they deploy their research work onto SURAgriD include the possibility of improving job performance on SURAgriD resources, increasing size and speed (scalability issues), and automating their processes of job submission, data movement and the dynamic management of jobs.

One of the more challenging (at least at present) aspects of grid-enabling an application that Prof. Punjabi's team may choose to address is the automation of the detection of the best resources on a grid at any particular point in

time. Currently available packages for this functionality are still maturing within the field of grid technology, but at a minimum the HU CFRT team will be able to manually check the SURAgriD portal to determine which resources have the smallest load and are available at a given time. They can then use the command line and GSISSH or an SSH program to logon to remote resources, generate proxies using grid-proxy-init, transfer files with globus-url-copy, and submit jobs using the Globus job manager. Alternately, the team will be able to access the SURAgriD Portal to carry out these same activities. The users will be able to create proxies with their user certificates by using the MyProxy utility either at the command-line (myproxy-init) or a Java MyProxy upload utility. Once the proxies are uploaded into their SURAgriD portal account, the user will be able to use the portal's file transfer and job submission GUIs. In both scenarios, the Globus job manager will forward the jobs to the local resource manager and scheduler (e.g., LSF, PBS, SGE) installed on the SURAgriD resource and the users can manually check on the status of their jobs.

Conclusion


The goal of the divertor tokamak (plasma) edge physics research being conducted by Prof. Punjabi's HU CFRT team is to calculate the structure and topology of the stochastic layer and the magnetic footprint in divertor tokamaks as different types of magnetic perturbations are introduced and to use the knowledge gained from the results to understand the nonlinear physics in the divertor tokamaks edge region. They're targeting the use of certain maps for specific application in General Atomics' DIII-D tokamak in the short-term. In the longer-term, they anticipate their work will be used in the ITER tokamak, on which construction is scheduled to begin in 2008 in Cadarache, France and from which the first plasma should be procured in approximately 2016⁶. There are numerous steps involved in their map research and Prof. Punjabi expects to use SURAgriD compute resources and associated services as much as possible in their work.

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 developing an infrastructure for access to heterogeneous resources and support for a dynamic and diverse application set.

For more information, or to join SURAgriD:

- <http://www.sura.org/SURAgriD>
- maryfran@sura.org

¹ <http://www.openmp.org/drupal/>

² <http://www.tecplot.com/>

³ <http://www.mathworks.com/products/matlab/>

⁴ <http://www.ptc.com/appserver/mkt/products/home.jsp?k=3901>

⁵ <https://www.pki.virginia.edu/sura-bridge/>

⁶ http://www.iter.org/a/index_nav_2.htm