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# Plasma Edge Kinetic-MHD Modeling in Tokamaks Using Kepler Workflow for Code Coupling, Data Management and Visualization

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**Abstract.** A new predictive computer simulation tool targeting the development of the H-mode pedestal at the plasma edge in tokamaks and the triggering and dynamics of edge localized modes (ELMs) is presented in this report. This tool brings together, in a coordinated and effective manner, several first-principles physics simulation codes, stability analysis packages, and data processing and visualization tools. A Kepler workflow is used in order to carry out an edge plasma simulation that loosely couples the kinetic code, XGC0, with an ideal MHD linear stability analysis code, ELITE, and an extended MHD initial value code such as M3D or NIMROD. XGC0 includes the neoclassical ion-electron-neutral dynamics needed to simulate pedestal growth near the separatrix. The Kepler workflow processes the XGC0 simulation results into simple images that can be selected and displayed via the Dashboard, a monitoring tool implemented in AJAX allowing the scientist to track computational resources, examine running and archived jobs, and view key physics data, all within a standard Web

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browser. The XGC0 simulation is monitored for the conditions needed to trigger an ELM crash by periodically assessing the edge plasma pressure and current density profiles using the ELITE code. If an ELM crash is triggered, the Kepler workflow launches the M3D code on a moderate-size Opteron cluster to simulate the nonlinear ELM crash and to compute the relaxation of plasma profiles after the crash. This process is monitored through periodic outputs of plasma fluid quantities that are automatically visualized with AVS/Express and may be displayed on the Dashboard. Finally, the Kepler workflow archives all data outputs and processed images using HPSS, as well as provenance information about the software and hardware used to create the simulation. The complete process of preparing, executing and monitoring a coupled-code simulation of the edge pressure pedestal buildup and the ELM cycle using the Kepler scientific workflow system is described in this paper.

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## 1 Introduction

In a tokamak fusion reactor, if the hot edge plasma, which has a density and temperature around $1\times10^{20}\ m^{-3}$ and 5 keV, respectively, is allowed to touch the material wall in an uncontrolled way, it can sputter the wall material into the plasma, which may degrade or extinguish the fusion burn and may shorten the wall lifetime to an unacceptable level. In an attempt to control this problem, all the modern tokamaks, including the planned ITER (International Thermonuclear Experimental Reactor), have been designed to divert the escaping edge plasma to a specific location called the "divertor chamber" by means of a magnetic field produced by external coils. The wall plates in the divertor chamber are then expected to be periodically replaced in a tokamak reactor.

The magnetic field lines inside the tokamak chamber are divided into two groups: one forming nested closed surfaces in the main chamber without touching the material wall, and the other leading to the divertor chamber. The boundary separating these two groups is the magnetic separatrix surface. The region outside the separatrix surface containing diverted field lines is called the "scrape-off" region, and the region inside the separatrix containing nested magnetic surfaces is called the "core" region. The plasma in the core region is hot and dense, while the plasma in the scrape-off region is cold and diluted (except just in front of the divertor plates).

Tokamak plasma transport is normally anomalous and is thought to be associated with small-scale plasma turbulence. When the heating power to the core plasma is above some threshold, it has been observed experimentally that there forms a thin plasma layer just inside the separatrix surface in which the plasma is almost free of turbulence; the cross-field transport rate is reduced to the neoclassical level [1] (neoclassical transport is a collisionally driven transport in an inhomogeneous magnetic field). This layer is called