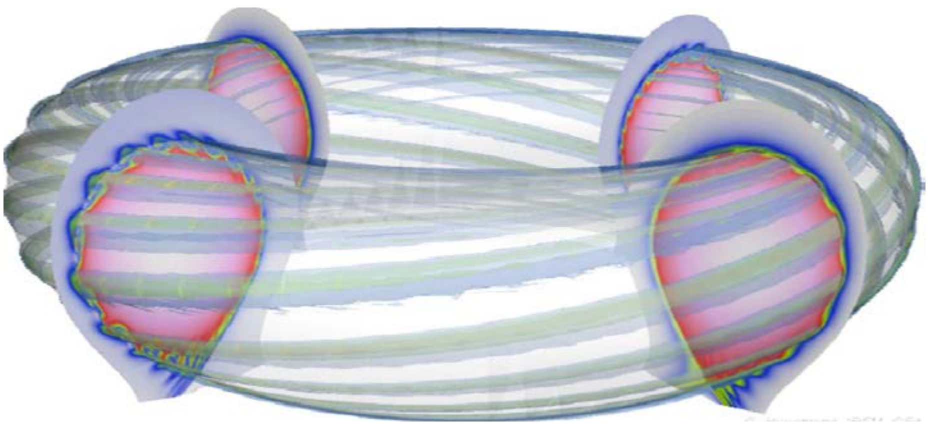
Challenges of First Principle Modelling and Role of HPC in Magnetic Fusion.

Presented by Marina Becoulet

Atomic Energy Commission, Institute for Magnetic Fusion Research, CEA/ IRFM, 13108, St. Paul-lez-Durance, France.

Fusion of light atoms occurring in the core of all stars including our Sun is well-known energy source in our Universe. In stars, the most common fuel is hydrogen, and gravity creates the conditions needed for fusion energy production such as plasma confinement and extreme density and temperature. However, these conditions are extremely difficult to reproduce on Earth. The goal of scientists for decades already is to develop clean, safe and limitless energy source based on fusion principle. The most developed concept is magnetically confined plasma heated by external sources (like RF waves or high-energy ion beams) to create conditions for hydrogen isotopes (deuterium and tritium) to fuse and release energy. The new era in the magnetic fusion started in 2007 with construction of the experimental device ITER in the frame of large international partnership of EU, China, Russia, USA, Japan, India and Korea. Magnetic fusion research now is going far beyond the academic studies facing ambitious challenges in the development of high confinement plasma scenarios combined with the high level of fusion plasma control. With this respect theory and predictive modelling plays crucial role for ITER and possible future reactor DEMO based on magnetic fusion. The most challenging in terms of HPC resources and numerical methods is so-called first principles modelling. The HPC challenges for this highly non-linear physics, involving 3D complex geometry, kinetic effects, can be extreme. The challenge stems from the wide range of spatial and time scales to be covered: from meters and seconds scale at the machine scale down to millimetres and wide range of the characteristic time scales from microseconds to hundreds of seconds. This complexity of magnetic fusion first principle modelling resulted in new numerical methods development particularly adapted to the highly non-linear problems demanding large memory, high level of parallelisation and long real time modelling (days, month). The present talk will describe specific challenges of modelling in fusion and some examples of recent progress in understanding of specific phenomena like small scale instabilities responsible for the turbulent transport and hence plasma confinement and large scale Magneto Hydro Dynamic (MHD) instabilities which define operational limits for given plasma scenario.



Non-linear MHD modelling of plasma edge relaxations due to Edge Localized Modes (ELMs) in a tokamak using JOREK code (courtesy to G. Huijsmans)