

Comparison between 2D and 3D Transport in ITER using a Citizen Supercomputer

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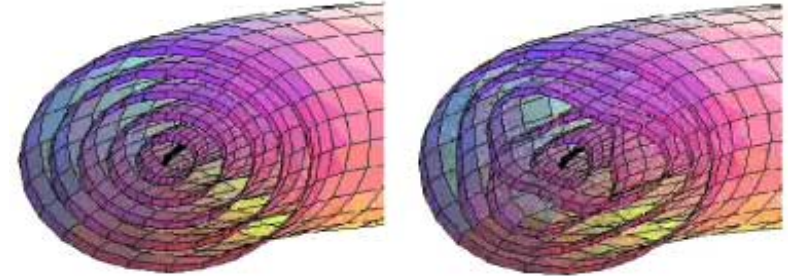
Introduction

- Fusion energy is one of the most promising energy sources for the future.
- In order to have fusion reactions inside a device, the plasma must reach the Lawson criteria: $n \cdot \tau_E \cdot T > L_0$
- Plasma transport is a very difficult subject to study since implies solving a 5D equation. Strong computation capacity needed.
- Transport can be diffusive/non diffusive and collisional/turbulent.
- We focus on solving the collisional transport in ITER using a citizen supercomputer called Ibercivis.

Effective Radius and G.C.

- **B** in fusion devices must form nested magnetic surfaces.
- Effective radius:

$$\Psi = \int_S \mathbf{B} \cdot d\mathbf{S}_\phi, \quad \rho = \sqrt{\frac{\Psi}{\Psi_{\text{Max}}}}$$



- Transport is much faster tangent to a magnetic surface than perpendicular. P, T, n, V depend only on ρ .
- Guiding Center approach, assuming cylindrical symmetry in velocity space: $(x, y, z, v_x, v_y, v_z) \rightarrow (X, Y, Z, v^2, \lambda)$
- Zero order: movement of the guiding center parallel to **B**.
- First order: perpendicular dynamics – Drift Velocities:

$$\mathbf{v}_D = \frac{\mathbf{E} \times \mathbf{B}}{B^2} + \frac{mv^2c^2}{eB^3} \left((1 - \lambda^2) \frac{1}{2} \mathbf{B} \times \nabla B + \frac{\mathbf{B} \times \mathbf{R}_c}{R_c^2} \right)$$

Helander, P. and Sigmar, D., Collisional Transport in Magnetized Plasmas, Cambridge University Press.

Montecarlo Method

- The plasma pdf evolution is described by a Fokker-Planck equation.

After linearization: $f_T = f_M + f$, a set of Stochastic Differential

Equations for a single particle trajectory can be derived:

$$d\mathbf{X}^i = \mathbf{F}^i(\mathbf{X})dt + \mathbf{G}_j^i(\mathbf{X}) d\mathbf{W}^j,$$

- \mathbf{F} and \mathbf{G} take into account convective and diffusive transport respectively. \mathbf{W} is a Wiener process: $d\mathbf{W} \sim N(0, \sqrt{dt})$

- We integrate test particle trajectories that interact with a static background.

- Ex.
$$\langle E \rangle = \frac{m}{2} \int f(x) v^2 dx \sim \frac{1}{N} \frac{m}{2} \sum v_i^2.$$

- ISDEP Code (Integrator of SDE for Plasmas)

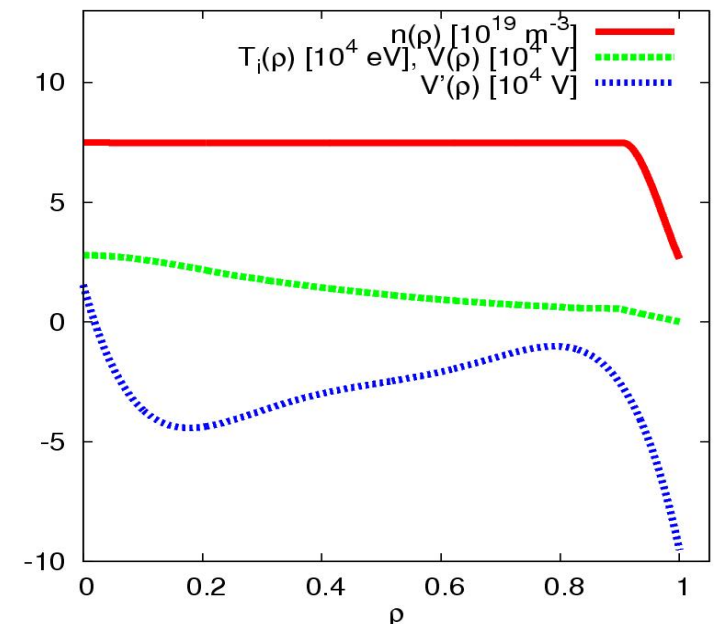
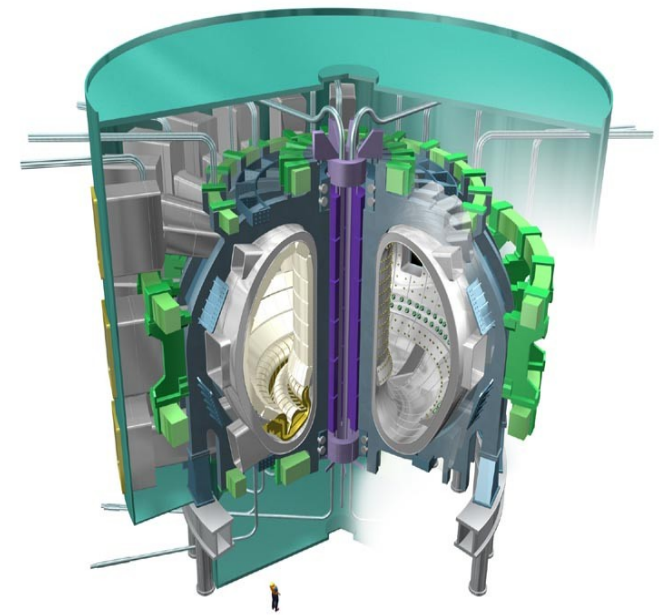
Castejón F. *et al.*, PPCF 2007

Kloeden P.E. and Platen E., *Numerical Solutions of Stochastic Differential Equations*, Springer Verlag, 1992.

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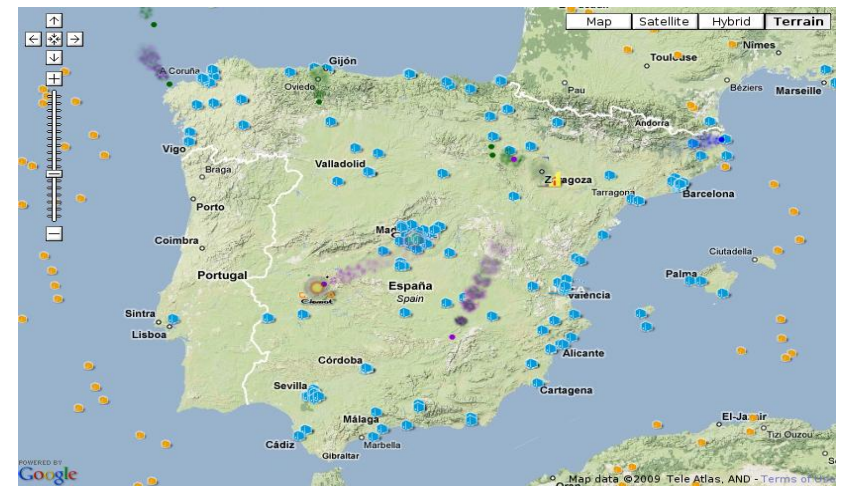
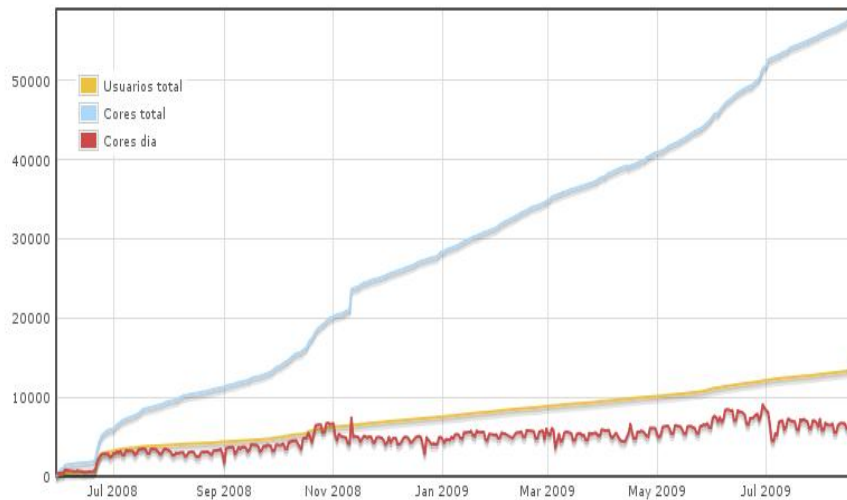
- Goal: show the viability of magnetic confinement fusion.
- Construction in progress (Cadarache, France).
- Huge: $R_0 \sim 6 \text{ m}$, $a \sim 2 \text{ m}$.
- 18 toroidal coils + 6 vertical field coils.
- Special case: this is a 3D tokamak. Toroidal asymmetries in the magnetic field – magnetic ripple.
- Caused by the finite number of toroidal coils and the nature of the Test Blanket Modules.
- Profiles and 2D-MHD equilibrium estimated with the HELENA code.

Boozer, A. *Reviews of Modern Physics*, 2004.



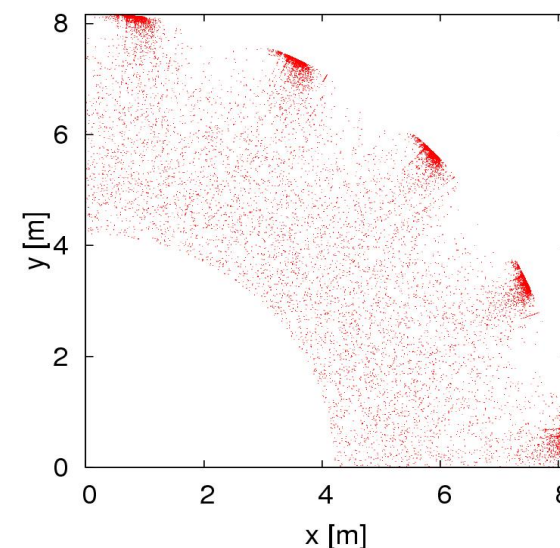
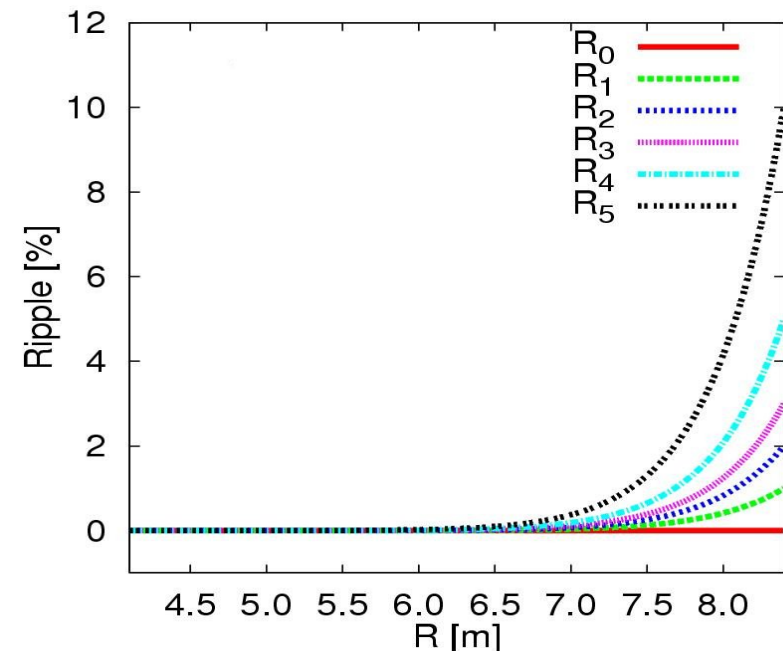
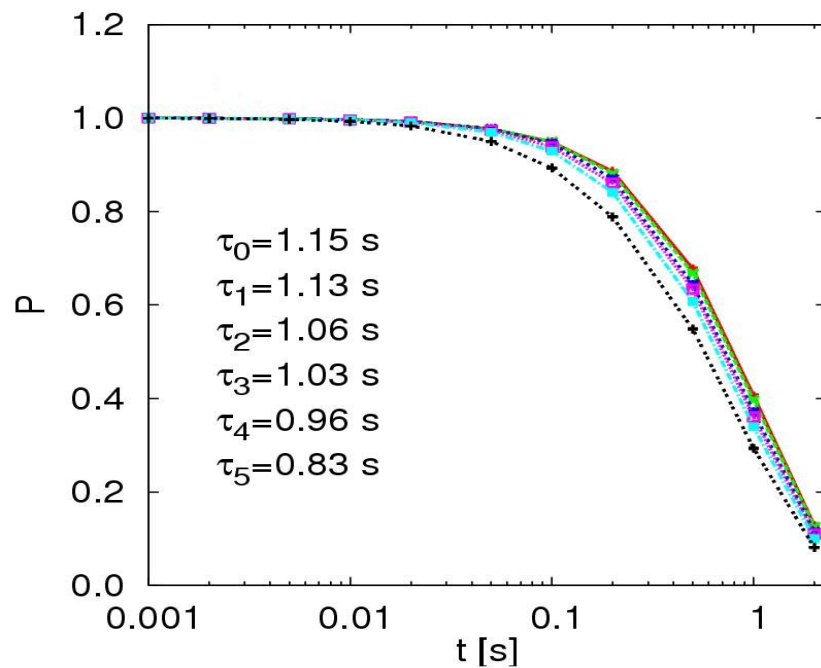
IBERCIVIS (www.ibercivis.es)

- It is a new (1 year old) volunteer computing platform based on BOINC (Berkeley Open Infrastructure for Network Computing) protocols with several science applications (fusion, material science, protein docking, ...).
- Recently it has reached the quantity of 8000 cores/day and more that 12000 users.
- Participants: BIFI, UCM, CIEMAT, CSIC, UEx, RedIris.
- ISDEP had to be adapted to the requirements of this platform.

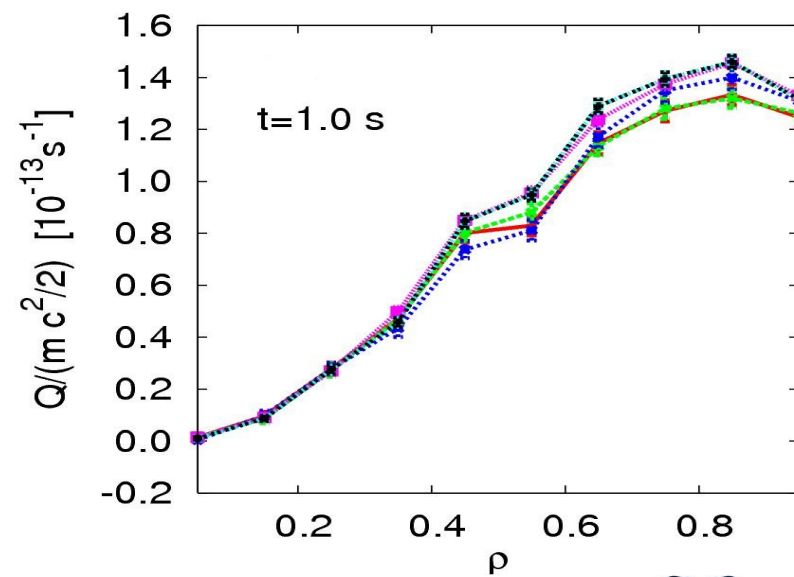
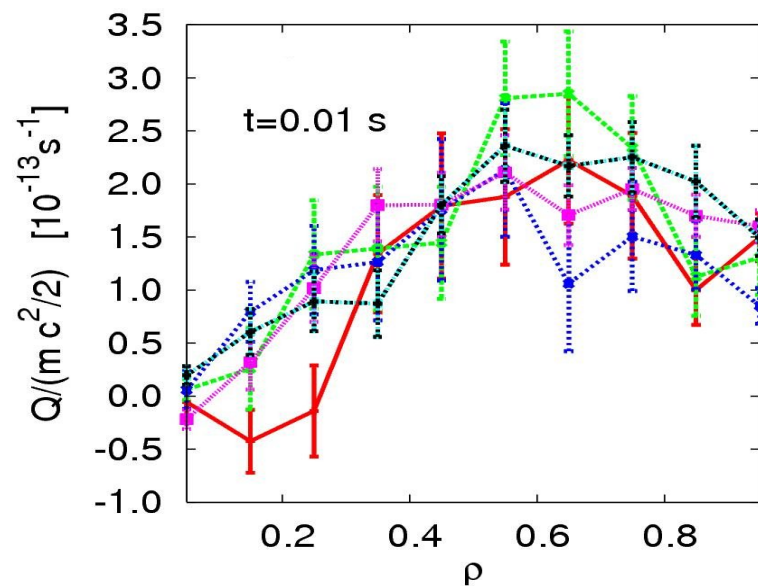
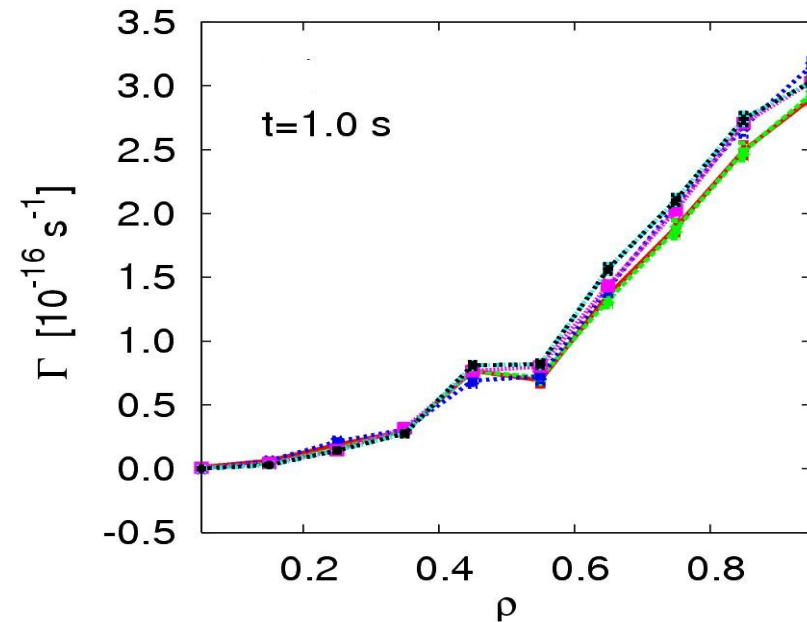
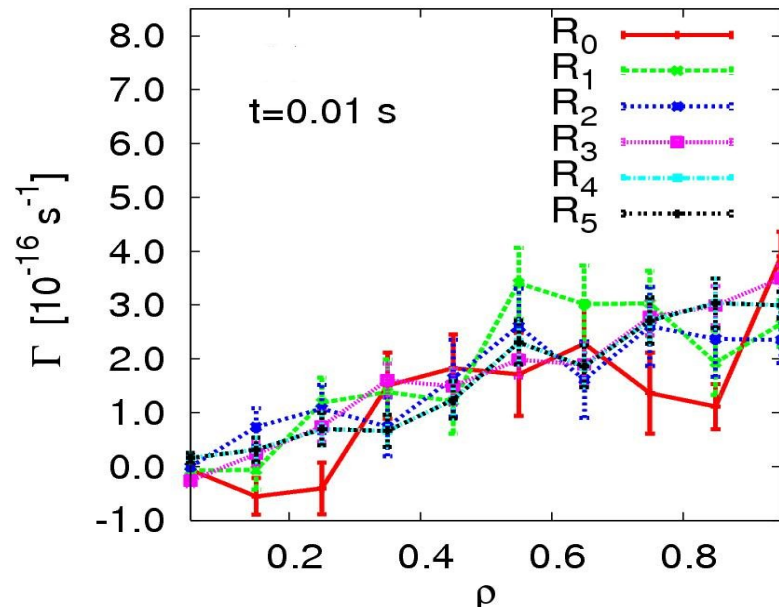


Numerical Results (I)

- We perform several simulations for different ripples, focusing in the measurements of the confinement times and radial particle and heat fluxes.



Numerical Results (II)



Conclusions

- The influence of ripple in ITER collisional transport is studied using a basic MHD equilibrium, introducing a perturbation to the magnetic field and running ISDEP, a 3D orbit code and distributed computing platforms.
- The ripple deteriorates the confinement, increasing radial fluxes.
- For long pulses it will affect the plasma edge.
- Volunteer computing can be useful in fusion science for distributed applications, with the added value of dissemination.
- More complex model for the reactor and the ripple is needed for a detailed study, i.e. toroidal asymmetries in the ripple.