ENERGETICS

MUR DM 118 - Development of self-consistent edge-core coupled transport models for impurities in Tokamaks

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Context of the research activity	The successfull candidate will work on the development of coupled self-consistent edge-core transport models for impurities in a Tokamak. The final aim is to understand how impurities released from the targets at the periphery of the plasma can penetrate deep in the SOL and finally penetrate in the confined plasma region. This will help assessing the compatibility of given target conditions with the requested reactor performance. Progetto finanziato dell'ambito del PNRR - DM 118/2023 - CUP E14D23001620006

	The targets of a Tokamak reactor will be a major source of impurities, which will propagate backwards toward the main plasma and, finally will penetrate in the confined region where they will dilute the main fuel and dissipate power by line radiation, unless they are fully ionized. The presence of impurities in the plasma is not necessarily detrimental. In fact, it is expected that a large radiation fraction, of the order of 90%, will be needed in a reactor to push the target power loads down to tolerable limits. Moreover, especially in the case of impurities released from a liquid metal divertor, a sufficiently large concentration in front of the target itself can trigger the vapor-shielding effect, which can contribute significantly to protect the target itself. However, impurity presence in the reactor environment must be carefully controlled, to avoid a too large accumulation in the core which would, in turn, be highly problematic. Controlling the impurities presence and accumulation requires a self-consistent description of their production and transport processes. Several source mechanisms are commonly implemented in edge-transport codes like, e.g., SOLPS-ITER, the most important ones being physical and, for C walls, chemical sputtering. On the other hand, other mechanisms like, e.g., evaporation (important in case of liquid metal divertors), are less widely implemented. Moreover, edge transport codes implement, most often, a very rough description of turbulent transport, assuming user-defined transport

Objectives	coefficients. While this might be acceptable in the SOL, where most of the relevant dynamics is driven by parallel transport, more accurate models are required in the internal plasma, where the only relevant transport is takes place across different magnetic surfaces, leading the development of different concentration profiles for the various charge-states. A reliable edge-core integrated transport model is not currently available, and it is believed that its development will constitute a significant advance in our capacity to efficiently design the next generation of fusion reactors. The project will start from the analysis of experimental data produced on the AUG tokamak on the source and transport of Tin impurities. This is selected since it is one of the possibilities for a Liquid Metal Divertor (LMD), which is known to allow obtaining very clean plasmas but whose concentration must be, on the other hand, controlled with extreme accuracy due to its very large radiative power. The target of the first phase will be the validation of the already available edge Liquid Metal transport models by benchmarking on with experimental data. Particular focus will be given to accurately reproducing the impurities radial profiles in the pedestal, assuming in a first stage a given SOL plasma (to be represented by proper model boundary conditions). This will be done using the transport models implemented in the ASTRA code. In a second stage, the so calibrated core transport model will be coupled with the edge code SOLPS-ITER, aiming at obtaining a self-consistent impurity description in both the peripherical and central plasma regions. Since the SOLPS-ITER is a 2D code while ASTRA is 1D this phase will require the development and testing of ad-hoc coupling procedures. Moreover, the core region is known to have a dynamic much slower than the SOL. The presence of several different time-scales in the process will introduce an additional layer complexity layer which the coupling procedure will need to handle, for example by alternating one call for the core transport module every many SOL transport calls. After the coupling procedure will prove to be stable and robust, the self-consistent edge-core transport model will be applied to refine the predictions obtained in the first validation stage, and to remove the ad-hoc parameters necessarily introduced in the original one-way model. The proposed project will focus mostly on the design of LMD solutions for future fusion reactors. However, its successful completion will result in the development of techniques and expertise capable of extension to several different context characterized by the important presence of impurities in the edge plasma of a tokamak experiment, like all currently considered fusion reactor scenarios.

Skills and competencies for the development of the activity	The successful candidate needs a solid background in fusion technology and plasma physics, with particular emphasis on transport in magnetically confined plasmas. Familiarity with modern HPC environments, the linux operative system are also useful, as well as previous experience with either edge or core transport codes, preferably SOLPS-ITER and/or ASTRA. Willingness and capacity to interact with a stimulating but challenging international scientific environment will also be considered.