Mathematical modelling of thermonuclear fusion plasmas

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Thermonuclear fusion plasmas are studied today in order to find solutions for longer-term, clean energy production. The behaviour of such plasmas is very complex, the main reason being the nonlinear and self-consistent nature of the coupled system «charged-particles $\Leftrightarrow$ fields». Collective effects play hence an important role and the underlying physics is very different from that of neutral gases.

The presence of several small (or large) parameters in fusion plasmas (e.g. the small Debye length, the high electron mobility, the low collisionality and of course the large B field) is indeed one source of many theoretical as well as numerical difficulties in the design of efficient models. To avoid wasting computational resources it is necessary to develop numerical models that behave well in the regimes where these parameters are small but not zero, and sometimes vary throughout the simulation domain. As such, reduced models are looked for, via asymptotic techniques or homogenization methods. As an example, kinetic equations, which bridge the microscopic dynamics with the macroscopic hydrodynamic equations, offer richer physics than macroscopic models and are computationally much more affordable than particle simulations.

Other physical phenomena, such as the electromagnetic screening, instabilities, turbulence, waves, chaos etc contribute to the fact that the plasma constitutes a remarkable domain of study. To give only one example, while in neutral gases only one type of wave occurs, the acoustic wave, in plasmas several types of waves develop, thanks to the collective behaviour of the plasma. These waves can be divided into two categories : the transverse electromagnetic waves, as for example the Alfén waves, and the longitudinal electrostatic waves, as the Langmuir or ion acoustic waves. All these phenomena lead to very intricate plasma dynamics and it is not surprising that a large part of the research is devoted to the description and understanding of wave propagation in plasmas.

Les trois orateurs (40 minutes par exposé) sont :

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