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A methodology for the rigorous verification of plasma simulation codes

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The methodology used to assess the reliability of numerical simulation codes constitutes the Verification and Validation (V&V) procedure. V&V is composed by two separate tasks: the verification, which is a mathematical issue targeted to assess that the physical model is correctly solved, and the validation, which determines the consistency of the code results, and therefore of the physical model, with experimental data. In the present talk we focus our attention on the verification, which in turn is composed by the code verification, targeted to assess that a physical model is correctly implemented in a simulation code, and the solution verification, that quantifies the numerical error affecting a simulation. Bridging the gap between plasma physics and other scientific domains, we introduced for the first time in our domain a rigorous methodology for the code verification, based on the method of manufactured solutions, as well as a solution verification based on the Richardson extrapolation [Riva *et al.*, Phys. Plasmas **21**, 062301 (2014)]. This methodology was applied to GBS [Ricci *et al.*, Plasma Phys. Controlled Fusion **54**, 124047 (2012), Halpern *et al.*, J. Comp. Phys. **315**, 388 (2016)], a three-dimensional fluid code based on a finite difference scheme, used to investigate the plasma turbulence in basic plasma physics experiments and in the tokamak scrape-off layer. Overcoming the difficulty of dealing with a numerical method intrinsically affected by statistical noise, we have now generalized the rigorous verification methodology to simulation codes based on the particle-in-cell algorithm, which are employed to solve Vlasov equation in the investigation of a number of plasma physics phenomena.