PoPe method for code verification and model reduction: Focus on numerical diﬀusion

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The Projection on Proper elements (PoPe) method is a code verification tool allowing to recover the equations that have most likely generated a set of data in the first place. A degree of verification can then be determined using a distance between the theoretical set of equations one wanted to implement in a code and the effective set of equations extracted from outputs of any simulations.

The extraction of the information is performed by searching for patterns in the unknown of an equation. One wants to project the whole information contained in the structure of an unknown over a list of operators computed at high accuracy. This projection determined the role of each operators assigning them weights, while any discrepancy not captured by the list of operators is stored in a residual. Studying weights and residual then defines the accuracy of the simulation. It is worth mentioning that reduction of model can be done in the same manner, just using a smaller list of operators and/or a list of simpler operators.

In terms of verification, this method is fundamentally different from classical ones since it is directly based on outputs of production simulations and it can be performed using simulations in any number of dimensions and any regimes, especially turbulent ones. Classic verification methods, instead, are based on specific code runs which might not be representative of production runs, typically not being as multiscale as production runs.

As an example, we focus in this talk on one interpretation of numerical error, the so called "numerical diffusion" of finite differences schemes. Two numerical implementations of a unique 2-fields 2D model of edge turbulence are compared, showing no diffusion appears in a pseudo-spectral approach while a clear diffusion appears in a finite volume approach. This results is recovered in the code TOKAM3X, a 5-fields 3D models implemented using a finite volume approach in limiter and X-point geometry. In the search for the H mode, in fully nonlinear / multi scale physics, knowing how accurate a simulation is might become a key element to avoid false interpretation of simulations and thus could better guide theoretical and numerical developments.