The need for mathematical innovation around design and optimization of non-equilibrium plasmas

Andrew Christlieb

Many of the viable fusion energy concepts involve control of non equilibrium plasmas. When seeking to optimize such systems, one needs models that go beyond the classic 5 moment model of gas dynamics (fluid models). The introduction of “kinetic” equations for modeling these systems revolves around the need to describe instabilities that are not captured by 5 moment models. With in these systems, the goal is to understand and mitigate non-equilibrium effects so as to maximize energy output. There are two key challenges around using kinetic models in this context. The first challenge is the curse of dimensionality. Kinetic models are naturally 6 dimensional plus time, and therefore traditional methods scale as $O(N^6)$. The second challenge is the need for structure and asymptotic preserving methods that permit the bridging of scales. Often there are key physical scale links both in space and time that one would like to step over in most settings but adaptively adjust under certain circumstances.

In this talk I will highlight the need for new mathematical innovation around scale bridging algorithms in fusion energy applications. I will then outline work being carried out by the Center for Hierarchical and Robust Modeling of Non-Equilibrium Transport (CHaRMNET) aimed at addressing the two key fundamental challenges. Finally, I outline highlight our work within CHaRMNET around blended computing as one approach to addressing the curse of dimensionality in a structure preserving context. Blended computing is the systematic hybridization of machine learning with traditional scientific computing. As stability is key in long time predictions, our approach to the design of machine learning surrogates in blended computing is to design surrogates such that they are mathematically consistent with the equations being solved. Here I will talk about this approach in the context of seeking to design scale bridging algorithms to study fuel optimization within capsules used in inertial confinement fusion systems.