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Development of a performance portable simulation code for fully kinetic simulations

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Abstract: With increasing computational capabilities over the past years it is possible to simulate more and more complex and accurate physical models. Gyrokinetic theory has enabled physicist to perform plasma simulations that are in fair agreement with experimental results in core physics. However, the assumptions made to derive gyrokinetics are unreliable in regimes of higher fluctuation amplitudes and stronger gradients, such as tokamak edge, and are by definition limited to the low frequency regime $\omega \ll \omega_{\mathrm{ci}}$. To study physical phenomena in these extreme conditions, we have developed a semi-Lagrangian algorithm to simulate ion-temperature gradient modes with the full 6D kinetic equations.

The algorithm has been extensively tested in the gyrokinetic regime, and simulations exploring new physics have been performed. Our work on the excitation of high-frequency waves $\omega \sim \omega_{\mathrm{ci}}$ will be presented and we will show numerical results of such excitations in non-linear ion temperature gradient simulations.

Performing a 6D kinetic simulation on this scale requires an immense amount of computational power and has high memory demands. For this purpose, we redeveloped our code from ground up with a focus on performance portability using the Kokkos library. This allows a hardware independent implementation of our algorithm which supports CPU and GPU architectures using a single code base. Facing the age of exascale computing, this gives the code the flexibility to be future-proof.

We will present parts of the implementation that enable this flexibility and show performance results, such as scaling behaviour on various architectures. These results demonstrate the performance potential of GPU accelerated computation but also reveal the bottleneck of inter-node communication, which is owed to the high dimensionality of the system.