HeAT - a distributed and GPU-accelerated tensor framework

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HeAT is an array-based numerical framework for large-scale processing in the Python programming language. Its goal is to bridge the gap between data analytics and machine learning libraries with a strong focus on on single-node performance, and traditional high-performance computing (HPC). For this, HeAT provides highly optimized algorithms and data structures for tensor computations using CPUs, GPUs and distributed cluster systems on top of MPI. The Python-first, NumPy-like interface integrates seamlessly with the existing data science ecosystem and makes it as effortless to write scalable data science applications. HeAT provides both, low-level array-based computations, as well as various higher-level algorithms, including among others neural networks, dimensionality reductions and clusterers. Compared with applications written in similar frameworks, such as Dask, HeAT achieves speedups of up to two orders of magnitude.

Macroscopic simulations of the microscopic quantum dynamics of laser-matter interaction to structure ultrafast light pulses

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Ultrashort pulses of coherent structured light are opening excellent opportunities to control the primary electronic response of matter at unprecedented temporal and spatial scales. During the last decade we have developed theoretical tools to simulate the intense laser-matter interaction processes that provide such light sources. In order to do that, one needs to fulfill sub-attosecond (10^{-18} sec.)/sub-nanometer (10^{-9} m.) resolution at the quantum scale and picosecond (10^{-12} sec.)/milimeter (10^{-6} m.) resolution at the macroscopic scale. Our micro+macroscopic methods, in combination with high-performance computing strategies, have allowed us to tackle this challenge. Our simulation results helped us not only to understand, but to propose new experiments that have been successfully realized by our collaborators. In particular, we have recently predicted the generation of new forms of structured laser light at the attosecond timescale with novel properties as the self-torque.