MAGNETIC RECONNECTION IN LASER-DRIVEN PLASMAS: FROM ASTROPHYSICS TO THE LABORATORY IN SILICO

Research Challenge
Magnetic reconnection is a fundamental plasma process that converts magnetic field energy into plasma kinetic energy through the breaking and rearrangement of magnetic field lines. The goal of this project is to use simulations to study particles from reconnection in varied plasma conditions, and in particular to investigate whether laser-driven plasma experiments could be used to study the particle acceleration properties of reconnection in the laboratory.

Methods & Codes
One of the most powerful tools for ab initio plasma simulation is the particle-in-cell (PIC) method, which treats the plasma as a collection of discrete simulation particles that interact via electromagnetic forces. The simulations for this project were run using the massively parallel, fully relativistic PIC code OSIRIS, and match the experimental conditions produced by the most energetic laser systems in the world, such as the National Ignition Facility.

Results & Impact
- The team demonstrated that electrons can be accelerated by reconnection with sufficient quantity and energy to be detected in the laboratory.
- Coulomb collisions, included in their simulations, have shown the importance of collisionality on the structure of the reconnection layer.
- Simulation results are being used to guide several experimental programs in the United States.
- The team has been developing simplex-in-cell (SIC), a novel method for plasma simulation that, under the right conditions, has been shown to reduce the number of required simulation particles by a factor of 1,000.

Why Blue Waters
This project required the use of large-scale 2D and 3D simulations with sufficient size and resolution to bridge the multiscale physics, from fluid dynamics to the kinetic microscopic processes. These computationally demanding simulations can require billions of simulation particles, and demand the cores, memory, and communication performance available on Blue Waters.