ICOPS-2016 – Plasma Simulation Mini-course

Information on Lectures

1. Carl Sovenic (University of Wisconsin)

Title: "Magnetohydrodynamics(MHD) and Extended-MHD"
Topics Covered:

I. Introduction - Provide a brief overview of plasma confinement, MHD equilibrium, stability, and the role of numerical computation.
II. Background
   a. Parallel current density and magnetic curvature are the primary sources of free energy.
   b. Resonances are weak spots in the configuration's ability to restore perturbations, and they lead to separation of spatial scales for macroscopic dynamics.
   c. Consider collisions and the separation of timescales.
III. Representative computational results from magnetically-confined plasmas (eg. Tokamak, Reversed-Field Pinch, etc)
IV. Models of macroscopic dynamics
   a. Primitive-equations systems describe the evolution of physical fields without order reduction.
   b. Reduced models separate temporal and spatial scales, and eliminate some to yield equations for potentials.
   c. Results on ideal-MHD spectra help illustrate distinct behavior.
V. Numerical approximations
   a. Time-stepping at various degrees of implicitness is used to address the separation of temporal scales.
      i. Differential approximation shows where explicit time-step limitations arise from waves.
      ii. Implicit methods for fusion MHD need to avoid large dissipative errors.
      iii. Crank-Nicolson has been the basis for a number of computations.
      iv. Semi-implicit methods represent an alternative line of development.
      v. The two-fluid version of the semi-implicit method is an implicit leapfrog.
   b. Spatial representation of macroscopic dynamics requires appropriate function spaces.
      i. Spectral pollution results from numerical coupling of physically distinct dynamics.
      ii. Requirements for second-order (eigenvalue) and first-order (time-dependent) models differ.
      iii. High-order and spectral methods help model anisotropy with evolving magnetic topology.

VI. Parallel computation - (?) Parallel computing is challenged by the need to solve large, sparse, ill-conditioned matrices.

VII. Conclusions - Summary of progress and open challenges

2. Thomas Mussenbrock (Ruhr-Universität Bochum, Germany)

Title (Tentative): “Modeling of nonequilibrium plasmas at high pressure”
Topics Covered (tentative):
- How to get from single particle to fluid description of plasmas?
- Which is the appropriate model for the situation under inspection?
- When are kinetic models needed?
- Which simulation strategies are appropriate in order to meet the goals of scientific accuracy and computational efficiency?

3. Richard Marchand (University of Alberta, Canada)

Title: Simulation of space environment interaction with satellites
Topics Covered:

- Space environment: thermal plasma, solar radiation, energetic particle fluxes, micrometeroids and space debris.
- Material interaction with space environment
    - Surface charging by
        - plasma particle collection,
        - photo-electron emission
        - secondary electron emission from electron and ion impact
        - reflection of incident particles
    - Deep dielectric charging from energetic penetrating particles.
    - Aging
- Kinetic Particle in Cell simulations
    - Different approaches: geometrical representations and simulation meshes.
    - Unstructured tetrahedral grids.
- Post-processing: Test-particle calculations
- Technical details
    - Material properties and data.
    - Validation with laboratory and in situ measurements.

4. Frederico Fiuza (Stanford (SLAC))

Title: “Kinetic simulations of intense laser-plasma interactions”
Topics Covered:

- Kinetic description of plasmas
- The particle-in-cell methodology
- High-performance computing
- Plasma-based accelerators
- Laboratory astrophysics
- Laser-solid interactions and ICF
- Hybrid approaches for multi-scale modeling
- Future prospects and challenges

5. Götz Lehmann (University of Duesseldorf, Germany)

Title: Vlasov Plasma Simulations and Applications
Topics Covered:

- From the N-body plasma model to the Vlasov equation
- The (relativistic) Vlasov-Maxwell system
- Application scenarios for Vlasov codes: From 2D to 5D phase-space
- Numerical methods for the Vlasov equation
  - Operator splitting
  - Interpolation
  - Semi-Lagrangian methods
- Parallelization strategies
- Examples for Vlasov Simulations in Laser-Plasma interactions
  - Comparing PIC to Vlasov simulations: Relativistic high harmonic radiation from overdense plasma targets
  - Kinetic effects in backscattering instabilities