Toward Optimal Multigrid Algebraic Solvers In Magnetohydrodynamics Simulations of Fusion Plasmas

Mark Adams

Magnetohydrodynamic simulations of tokamak fusion plasmas exhibit a large separation of temporal scales. To overcome the temporal stiffness associated with the fast compressive and Alfven waves in single-fluid resistive MHD, we consider the development of optimal implicit algorithms. We strive to achieve ”textbook” multigrid efficiency in which the set of nonlinear equations is solved to discretization accuracy at each time step, with a cost equivalent to a few (less than 10) residual calculations (or work units). We present results from a few canonical MHD problems: magnetic reconnection in 2D and in the presence of a strong guide field.
Acknowledgments: RS supported by USDOE Contract no. DE-AC020-76-CH03073 at PPPL, Princeton University.

Plasma Turbulence and Transport in a Ring Dipole System

Sumire Kobayashi

Gyrokinetic GS2 simulations of plasma turbulence and particle and heat transport in a dipole magnetic field geometry created by a ring current are presented. These simulations are relevant to the levitated dipole experiment (LDX) at MIT, and also have potential applications to magnetospheric dipole fields. In addition to ideal interchange and ballooning modes, a non-MHD mode known as the entropy mode is present in this system. The entropy mode has a scale length smaller than ideal modes (eg, $k_\perp \rho_i \sim 1$) but comparable growth rates. Considering parameter regimes that are ideally stable, we explore the physics of turbulent transport generated by a entropy mode, finding enormous variation in the nonlinear dynamics as a function of the density and temperature gradients and the plasma collisionality. This variation is explained in part by the damping and stability properties of spontaneously formed zonal flows in the system.

An Analytic Study of the Perpendicularly Propagating Electromagnetic Drift Instabilities in the Magnetic Reconnection Experiment

Yansong Wang

A local linear theory is proposed for a perpendicularly propagating drift instability driven by relative drifts between electrons and ions. The theory takes into account local cross-field current, pressure gradients and modest collisions as in the MRX. The unstable waves have very small group velocities in the direction of pressure gradient, but have a large phase velocity equal to the relative drift velocity between electrons and ions in the direction of cross-field current. By taking into account the electron-ion collisions and applying the theory in the Harris sheet, we establish this instability could be excited in the center of the Harris sheet and will have enough e-foldings before it propagates out of the unstable region.

Exact integral identities for the Sinh-Poisson equation

Ryan White

An integral identity which must be satisfied by any solution to the Sinh-Poisson equation is derived. The derivation is based on a famous analysis [G. H. Derrick, Journal of Mathematical Physics 5, 1252 (1964)] which demonstrates the impossibility of local solutions (solitons) to a wide class of nonlinear field equations. The method of proof employs a scale variation of the action integral that yields an integral identity which is inconsistent with energy conservation. The method used to derive the integral identity is very general and can be immediately applied to any differential equation derivable from an action principle. However, the scale change used is not compatible with a finite boundary. Therefore the present work employs a distinct but related variation that is sufficiently general to be used on any compact boundary and still allows for the derivation of a nontrivial integral relation. This technique is applied to the Sinh-Poisson equation which governs the equilibrium electrostatic potential for a fully-ionized plasma. We consider both a square and circular boundary and derive an integral relation which must hold for arbitrary boundary data.

Thermonuclear Dynamo inside an Alfven Black Hole

Friedwardt Winterberg

As in an acoustic black hole where the fluid is moving faster than the speed of sound and where the sound waves are swept along, in an Alfvén black hole the plasma is moving faster than the Alfvén velocity, with the Alfvén waves swept along and eliminated as the cause of the magneto hydrodynamic instabilities. To realize an Alfvén black hole, it is proposed to bring a plasma into rapid rotation by radially arranged lumped parameter transmission lines intersecting the plasma under an oblique angle. The rotating plasma slides frictionless over magnetic mirror fields directed towards the rotating plasma, with the mirror fields generated by magnetic solenoids positioned at the end of each transmission line. It is then shown that, with this configuration one can realize a thermonuclear dynamo, which also can serve as the analogue of a magnetar.