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Abstracts of Papers to Appear

An Implicit, Nonlinear Reduced Resistive MHD Solver. L. Chacón,* D. A. Knoll,† and J. M. Finn.* *MS K717, PO Box 1663, Los Alamos National Laboratory, Los Alamos, New Mexico 87545; and †MS B216, PO Box 1663, Los Alamos National Laboratory, Los Alamos, New Mexico 87545.

Implicit time differencing of the resistive magnetohydrodynamic (MHD) equations can step over the limiting time scales—such as Alfvén time scales—to resolve the dynamic time scales of interest. However, nonlinearities present in these equations make an implicit implementation cumbersome. Here, viable paths for an implicit, nonlinear time integration of the MHD equations are explored using a 2D reduced viscoresistive MHD model. The implicit time integration is performed using the Newton–Raphson iterative algorithm, employing Krylov iterative techniques for the required algebraic matrix inversions, implemented Jacobian-free (i.e., without ever forming and storing the Jacobian matrix). Convergence in Krylov techniques is accelerated by preconditioning the initial problem. A "physics-based" preconditioner, based on a semiimplicit approximation to the original set of partial differential equations, is employed. The preconditioner employs low-complexity multigrid techniques to invert approximately the resulting elliptic algebraic systems. The resulting 2D reduced resistive MHD implicit algorithm is shown to be successful in dealing with large time steps (on the order of the dynamical time scale of the problem) and fine grids. The algorithm is second-order accurate in time and scalable under grid refinement. Comparison of the implicit CPU time with an explicit integration method demonstrates CPU savings even for moderate (64×64) grids, and close to an order of magnitude in fine grids (256×256).

A Two-Scale Method for the Computation of Solid–Liquid Phase Transitions with Dendritic Microstructure. Christof Eck, Peter Knabner, and Sergey Korotov. Institute for Applied Mathematics, University of Erlangen—Nürnberg, Erlangen D-91058, Denmark.

A two-scale model for liquid–solid phase transitions with equiaxed dendritic microstructure in binary material in the case of slow solute diffusion is presented. The model consists of a macroscopic energy transport equation and, for each point of the macroscopic domain, a local cell problem describing the evolution of the micro-structure and the microsegregation. It is derived by formal homogenization of a sharp interface model, including the Gibbs–Thomson law and kinetic undercooling. Based on the two-scale model, a numerical two-scale method for the simulation of phase transitions with dendritic microstructure is developed, and numerical examples are presented.

Smoothness Indicator for Adaptive Algorithms. Smadar Karni,* Alexander Kurganov,*,† and Guergana Petrova.*,‡ *Department of Mathematics, University of Michigan, Ann Arbor, Michigan 48109-1109; †Mathematics Department, Tulane University, New Orleans, Louisiana 70118; and ‡Department of Mathematics, Texas A&M University, College Station, Texas 77843-3368.

The formation of shock waves in solutions of hyperbolic conservation laws calls for locally adaptive numerical solution algorithms and requires a practical tool for identifying where adaption is needed. In this paper, a new smoothness indicator (SI) is used to identify "rough" solution regions and is implemented in locally adaptive algorithms. The SI is based on the weak local truncation error of the approximate solution. It was recently reported where error analysis and convergence properties were established. The present paper is concerned with its implementation in scheme adaption and mesh adaption algorithms. The SI provides a general framework for adaption and is not restricted to a particular discretization scheme. The implementation in this paper uses a central-upwind scheme. The extension of the SI to two space dimensions is given. Numerical results in one and two space

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dimensions demonstrate the robustness of the proposed SI and its potential in reducing computational costs and improving the resolution of the solution.

A Hierarchical $\mathcal{O}(N)$ Force Calculation Algorithm. Walter Dehnen. Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany.

A novel code for the approximate computation of long-range forces between N mutually interacting bodies is presented. The code is based on a hierarchical tree of cubic cells and features mutual cell–cell interactions which are calculated via a Cartesian Taylor expansion in a symmetric way, such that total momentum is conserved. The code benefits from an improved and simple multipole acceptance criterion that reduces the force error and the computational effort. For $N \gtrsim 10^4$, the computational costs are found empirically to rise sublinearly with N. For applications in stellar dynamics, this is the first competitive code with complexity $\mathcal{O}(N)$; it is faster than the standard tree code by a factor of 10 or more.

A Slope-Update Scheme for Compressible Flow Simulation. Kun Xu. Department of Mathematics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong.