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POSTER ABSTRACTS

Albaran, Robert	<p>Kinetic Modeling of Ionospheric Outflows in Pressure Cooker Environments</p> <p>Robert Albaran, University of California, Los Angeles, USA Matthew Zettergren, Embry-Riddle Aeronautical University, USA Doug Rowland, NASA Goddard Space Flight Center, USA Jeff Klenzing, NASA Goddard Space Flight Center, USA James Clemmons, The Universi</p> <p>Plasma escape from the high-latitude ionosphere (ion outflow) serves as a significant source of heavy plasma to magnetospheric plasma sheet and ring current regions. Outflows alter mass density and reconnection rates, hence global responses of the magnetosphere. A new fully kinetic and semi-kinetic model is constructed from first principles which traces large numbers of individual O+ ion macro-particles along curved magnetic field lines, using a guiding-center approximation, in order to facilitate calculation of ion distribution functions and moments. Particle forces include mirror and parallel electric field forces, a self-consistent ambipolar electric field, and a parameterized source of ion cyclotron resonance (ICR) wave heating, thought to be central to the transverse energization of ions. The model is initiated with a steady-state ion density altitude profile and Maxwellian velocity distribution and particle trajectories are advanced via a direct simulation Monte Carlo (DSMC) scheme. This outlines the implementation of the kinetic outflow model, demonstrates the model's ability to achieve near-hydrostatic equilibrium necessary for simulation spin-up, and investigates L-shell dependent wave heating and pressure cookers scenarios. This provides quantitative means to interpret sounding rocket data and related remote sensing approaches to studying ion outflows and serves to advance our understanding of the drivers and particle dynamics in the auroral ionosphere and to improve data analysis for future sounding rocket and satellite missions.</p>
Boyd, Brendan	<p>Low Mach Number Simulations of the Convective Urca Process</p> <p>Brendan Boyd, Stony Brook University, USA Alan Calder, Stony Brook University, USA Dean Townsley, University of Alabama, USA</p> <p>A proposed setting for thermonuclear (Type Ia) supernovae is a white dwarf that has gained mass from a companion to the point of carbon ignition in the core. There is a simmering phase in the early stages of burning that involves the formation and growth of a core convection zone. One aspect of this phase is the convective Urca process, a linking of weak nuclear reactions to convection which may alter the composition and structure of the white dwarf. Convective Urca is not well understood and requires 3D fluid simulations to realistically model. Additionally, the convection is relatively slow (Mach number less than 0.005) so a low-Mach method is needed. Using the MAESTROeX low-Mach hydrodynamic software, we present full 3D simulations of the A=23 convective Urca process. These results point to the proper initial conditions needed for the simulation to quickly settle into a quasi-steady state. Our findings on the extent of mixing across the Urca shell, the characteristic velocities of the flow and the energy loss rates can be used to inform 1D stellar models which track the longer-timescale evolution. This research was supported in part by the US Department of Energy (DOE) under grant DE-FG02-87ER40317</p>
Chen, Zhi	<p>Sensitivity of He Flames in X-ray Bursts to Nuclear Physics</p> <p>Zhi Chen, Stony Brook University, USA</p> <p>Through the use of axisymmetric 2D hydrodynamic simulations, we further investigate laterally propagating flames in X-ray bursts (XRBs). Our aim is to investigate the sensitivity of a propagating helium flame to different nuclear physics. Using the \castro simulation code, we confirm the phenomenon of enhanced energy generation shortly after a flame is established after by adding $\{C\}$ to the network, in agreement with the past literature. This sudden outburst of energy leads to a short accelerating phase, causing a drastic alteration in the overall dynamics of the flame in XRBs.</p>

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Crawford, Chris	<p><i>The Scaling of Vortical Electron Acceleration in Thin-Current Magnetic Reconnection and Its Implications in Solar Flares</i></p> <p>C. Crawford, University of Alabama in Huntsville, USA H. Che, University of Alabama in Huntsville, USA A. O. Benz, University of Applied Sciences and Arts Northwestern Switzerland, Switzerland</p> <p>How magnetic reconnection (MR) accelerates electrons to a power-law energy spectrum in solar flares is a challenging problem in solar physics. To investigate this problem, we explore the scaling of a kinetic model proposed by Che and Zank (2020) (CZ) and compare it to observations to evaluate this model. We first propose small-scale MRs are triggered in thin current sheets ($\sim d_i$, d_i the ion inertial length) that are generated by Kelvin-Helmholtz instability (KHI) in large-scale MR. Then we use kinetic theory and particle-in-cell (PIC) simulations to analyze the impact of domain size on the evolution of electron KHI (EKHI) in thin-current-sheet MR. We find that the duration of the growth stage of the EKHI ($t_G \sim \Omega_{ce}^{-1}$) is short and remains nearly unchanged since Ω_{ce} is independent of domain size. The quasi-steady stage of the EKHI t_{MR} is dominant and scales linearly with the size of the simulations as L/v_{A0}, v_{A0} is the Alfvén speed. We use the analytical electron energy spectrum obtained by CZ to calculate the continuous temporal evolutions of the spectra from PIC simulations. Using a linear scaling method drawn from the PIC simulations, we scale the spectra and the acceleration region sizes to observational scales and find them in good agreement with typical soft-hard-harder solar electron energy spectra and solar flare acceleration region spatial scales, suggesting that we can use PIC MR simulations to investigate the observational electron energy spectral evolution of solar flares if the ratio t_G/t_{MR} is sufficiently small $\sim 15\%$.</p>
Deuja, Atit	<p><i>Modeling of Electron Acceleration During the Contraction of Magnetic Islands</i></p> <p>Atit Deuja, University of Alabama in Huntsville, USA Haihong Che, University of Alabama in Huntsville, USA</p> <p>Magnetic reconnection releases the magnetic energy through the contraction of multi-magnetic islands generated by tearing instability leading to the electron acceleration as proposed by Drake et. al in 2006. However, how the released magnetic energy is converted into electron's kinetic energy is still not well understood. We model this adiabatic process assuming that the contraction of magnetic islands induces an electric field such that the curl of induced electric field is proportional to the magnetic field of the islands and approximate the magnetic island with an ellipse. Under this model, we show that the energy gain is achieved through the work of electrons along the inductive (reconnection) electric field. We further show that the curvature drift term dominates the energy gain. We compared our model with the magnetic islands formed by tearing instability in a 2.5D particle-in-cell simulation of magnetic reconnection and found the model consistent with the simulation.</p>
Feldman, Catherine	<p><i>Challenges Modeling the Low-Luminosity Type Iax Supernovae</i></p> <p>Catherine Feldman, Stony Brook University, USA Ellis Eisenberg, Half Hollow Hills High School West, USA Dean M. Townsley, The University of Alabama, Tuscaloosa, USA Alan C. Calder, Stony Brook University, USA</p> <p>Type Iax supernovae, one class of very dim events, produce a slow moving, sparse ejecta that presents challenges for simulation. These events are hypothesized to be created from deflagration (subsonic burning), without a subsequent supersonic detonation, of a white dwarf star. The deflagration gives the star time to react and expand, quenching the burning so that the majority of the mass remains unburned and gravitationally bound. The resulting system is a hot, dense core surrounded by sparse material that cools as it expands outwards. The lack of a vigorous explosion makes the results of simulations especially sensitive to the initial conditions and presents additional challenges for the system's evolution. Here, we present an investigative suite of 30 simulations of a hybrid C/O/Ne WD undergoing a deflagration using FLASH, a multi-scale, multi-physics software instrument. We explore how the final state of the simulation changes as we vary the character of the early stages of burning, which influences the outcome of the explosion. We also discuss how the "fluff" parameters, i.e. those pertaining to the low-density gas on the grid in lieu of vacuum, affects the geometry of the deflagration and inhibits the ejecta as it expands. We also discuss strategies for simulating the expansion of the ejecta to late times, which is more challenging than for simulations of SNIa due to the lower ejecta velocities exhibited by SNIax simulations. Finally, we present a comparison between our simulation and observations of these events.</p> <p>The authors would like to thank Stony Brook Research Computing and Cyberinfrastructure, and the Institute for Advanced Computational Science at Stony Brook University for access to the SeaWulf computing system, which was made possible by a \$1.4M National Science Foundation grant (#1531492). This research was also supported in part by the US Department of Energy (DOE) under grant DE-FG02-87ER40317 and in part by the US National Science Foundation (NSF) under grant OAC 1927880.</p>

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Glines, Forrest	<p><i>Exascale Simulations of Magnetized AGN Jets on Frontier with Performance Portable MHD</i></p> <p>Forrest Glines, Philipp Grete, Benjamin Wibking, Deovrat Prasad, Brian O'Shea</p> <p>The magnetically collimated jets emitted by active galactic nuclei (AGN) at the center of galaxy clusters and groups are widely agreed to play a key role in the regulation of cold gas in these systems. The effect of the AGN jet's magnetic fields on the environment, however, is still being explored. These injected magnetic fields can affect dynamics on the large scales of the hundreds of kiloparsecs jet down to the small scales of sub-parsec plasma instabilities. Modeling large portions of this span of dynamical ranges requires great computing resources such as those provided by Frontier, the world's first exascale supercomputer made available this year. To perform such simulations on exascale supercomputers, we developed AthenaPK, an open source magnetohydrodynamics (MHD) code with adaptive mesh refinement (AMR) that is performance portable; AthenaPK runs at high performance on several new computer architectures comprising exascale supercomputers. We present simulations executed on Frontier of magnetized AGN feedback in galaxy clusters and groups. We will also discuss our experiences crafting the performance portable code AthenaPK and using it on the Frontier supercomputer. With exascale resources, we can model the plasma at much higher resolution with higher fidelity than previously possible, allowing us to resolve more physics within these systems. (LA-UR-23-25749)</p>
Johnson, Eric	<p><i>Simulating Lateral Flame Propagation in Type I X-ray Bursts</i></p> <p>Eric T. Johnson, Stony Brook University, USA Michael Zingale, Stony Brook University, USA</p> <p>Type I X-ray bursts are thermonuclear explosions that occur on the surfaces of accreting neutron stars. They allow us to probe neutron star properties such as radius and spin rate, and are especially interesting due to their accessible recurrence times of hours to days. One-dimensional simulations can accurately reproduce observed recurrence times and light curves, but not features from multidimensional effects such as convection and flame propagation. Multi-dimensional simulations are much more computationally expensive due to the large range of physical scales involved. We have been performing two-dimensional hydrodynamics simulations of a mixed H/He burst to investigate the structure of laterally-propagating flames during the burst rise. Previous work from our group was limited to pure helium bursts, but performance improvements to our code have allowed us to use larger reaction networks that include hydrogen burning.</p>
Mao, Huaqing	<p><i>A new 3d1d Approach to Stellar Evolution Simulations</i></p> <p>Huaqing Mao, University of Minnesota, USA Paul Woodward, University of Minnesota, USA Falk Herwig, University of Victoria, Canada Pavel Denissenkov, University of Victoria, Canada Simon Blouin, University of Victoria, Canada</p> <p>Stellar evolution is computed in 1D, because otherwise time steps would need to be small enough to capture the 3-D gas behavior, such as turbulent convection. 1-D models of convection designed for use in stellar evolution codes have consequently been a key enabling technology. I will describe a set of detailed 3-D simulations of core convection and material mixing in main sequence massive stars, showing how these simulations have informed a new model for the convection zone and its region of convective penetration into the stably stratified layers above it. This new 1-D model has no free parameters, but it does require the knowledge of the kinetic energy dissipation rate as a function of radius in the convection zone. I will discuss how this dissipation function can be obtained with a coarse and short 3-D simulation, and how changes in this function as the star evolves can be obtained by means of interpolation between a small number of such 3-D solutions. We are implementing this new approach to 1-D stellar evolution simulation in the MESA code, and this work will be described.</p>

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Narrett, Isaac	<p><i>Exploring Impact Plasma Amplification of the Ancient Lunar Magnetosphere</i></p> <p>I. S. Narrett, Massachusetts Institute of Technology, USA R. Oran, Massachusetts Institute of Technology, USA Y. Chen, Plasma Physics Laboratory, USA G. Toth, University of Michigan, USA Katarina Miljković, Curtin University, Australia B. P. Weiss, Mass</p> <p>The source of the lunar crustal field is a longstanding mystery. The Moon lacks a global magnetic field, yet spacecraft observations and laboratory studies of Apollo samples have identified natural remanent magnetization that formed in an ancient magnetic field, possibly reaching $>30 \mu\text{T}$. However, the inferred size of the lunar core suggests it may be too small to produce an Earth-like dynamo, as core convection dynamo scaling laws struggle to account for surface fields above $\sim 1 \mu\text{T}$. In this presentation, we explore a key alternative hypothesis that the low dynamo field was transiently amplified by impact-generated plasmas. However, this hypothesis has not been tested using self-consistent magnetohydrodynamic (MHD) simulations. We combine the results from iSALE-2D shock physics impact simulations and MHD simulations using BATS-R-US to simulate a large basin-forming impact within a lunar magnetosphere. The magnetic field inside the body evolves according to the magnetic diffusion equation (i.e., there is no plasma flow), while outside the body, the plasma is infinitely conducting and the magnetic field evolves according to the induction-advection equation. Importantly, the two fields are coupled to the evolution of the impact vapor cloud engulfing the Moon. Initial results show a complex interaction between the vapor and field, including boundary currents, compression of the magnetospheric field to produce transient enhancement in the cloud periphery, diffusion of the enhanced field into the crust, and dissipation of the field in the various layers of the Moon. Initial results show that the dipole field is amplified by $\sim 40\%$ relative to the magnetospheric field (i.e., from 1800 nT to 2600 nT) and lasts for a duration of minutes. This suggests that impact plasma could modify the field recorded by impact melt by a significant amount, implying that lunar remanent magnetization may not be entirely a record of a pure dipole field. This suggests that impact plasma could modify the field recorded by impact melt by a significant amount, implying that the magnetization may not be a record of a pure dipole field. Additionally, this result may highly depend on the location of the impact relative to the dipole axis, which will be explored in future work.</p>
Phillips, David	<p><i>An Operator Splitting Approach to Highly Magnetised Relativistic Magnetohydrodynamics</i></p> <p>David Phillips, University of Leeds, UK Serguei Komissarov, University of Leeds, UK</p> <p>Conservative schemes are an extremely powerful tool in Relativistic Magnetohydrodynamics for modelling astrophysical phenomena. But while these able to handle low magnetisation with ease (where the ratio of magnetic components to inertial components is small), these schemes show significant failures at higher magnetisation - in some cases, failing even at ratios as small as 1. On the other extreme, Force-free models that neglect the inertial components entirely are unable to resolve crucial details such as current sheets. Here we present a novel operator splitting approach to the high-magnetisation regime of special relativistic magnetohydrodynamics, and describe 1D and 2D test simulations demonstrating its accuracy in both the low-and high-magnetisation regimes.</p>
Sciola, Anthony	<p><i>A New High-performance Inner Magnetosphere Simulator for Integrated Global Geospace Modeling</i></p> <p>Anthony Sciola, JHU/APL, USA Kareem Sorathia, JHU/APL, USA Slava Merkin, JHU/APL, USA Shanshan Bao, Rice University, USA Frank Toffoletto, Rice University, USA Adam Michael, JHU/APL, USA Harry Arnold, JHU/APL, USA</p> <p>Formation of the ring current within the inner magnetosphere is a crucial element of Earth's magnetospheric response to heightened solar wind activity. The ring current is central to the strong storm-time coupling of disparate plasma and neutral gas populations of the geospace system, including the global magnetosphere, ionosphere, plasmasphere and exosphere. As such, simulating the ring current from first-principles remains a great challenge to modelling the geospace environment. Recent efforts to model the geospace system in a more holistic manner and at unprecedented resolution and performance have created demand for an inner magnetosphere model designed with these challenges in mind. We present progress towards such a model, named RAIJU, whose key features include a highly conservative scheme with 7th order reconstruction, adaptive domain evolution to optimize time stepping, and energy-resolved coupling between the modeled ionosphere, plasmasphere and exosphere. RAIJU is being developed to be compatible with the Multiscale Atmosphere Geospace Environment (MAGE) model developed by the NASA Drive Science Center for Geospace Storms (CGS).</p>

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Seo, Jeongbhin	<p>A New WENO Magnetohydrodynamic Code with a High-Order Constrained Transport Scheme</p> <p>Jeongbhin Seo, Ulsan National Institute of Science & Technology, Korea Dongsu Ryu, Ulsan National Institute of Science & Technology, Korea</p> <p>We have developed a new magnetohydrodynamic (MHD) code for astrophysical applications, which is based on a fifth-order finite-difference weighted essentially non-oscillatory (WENO) scheme and a fourth-order strong stability-preserving Runge-Kutta (SSPRK) time-integration scheme. In particular, to match the high-order accuracy of the WENO scheme, we have implemented a new constrained transport (CT) algorithm of high-order accuracy. In this talk, we describe the MHD code and present its performance. We demonstrate that with the new CT scheme, the code achieves fifth-order accuracy in wave decay tests, including a circularly polarized Alfvén wave propagation test. We further demonstrate the high accuracy and robustness of the code through tests involving complex flows.</p>
Smith Clark, Alexander	<p>pynucastro 2.0: New Features and Implementation of a Python Library for Nuclear Astrophysics.</p> <p>Alexander Smith Clark, Stony Brook University, USA</p> <p>pynucastro is an open-source python library that provides the ability to construct and explore astrophysical nuclear reaction networks, providing interacting visualization tools and the capability of interfacing them into languages such as python and C++. In our new version of pynucastro, we implemented new plots that highlight the importance of a rate, nuclei and initial composition, to a particular network. We enabled support to compute the inverse, endothermic, baryonic reaction rates in terms of its exothermic baryonic counterparts, including support of the nuclear partition functions required in high temperature domains. Furthermore, we have included the classical coulomb screening effects and the ability to compute the Nuclear Statistical Equilibrium (NSE) composition, given the density and temperature on which the reaction network takes place. Finally, it is important to highlight that pynucastro has opened a new set of possibilities, and perspectives from the community and developers, such as the implementation of quantum screening, the support of the Helmholtz EOS, and the implementation of network-reduction methods.</p>
Willcox, Don	<p>Emu: An Open-Source Particle-in-Cell Code for Multidimensional Quantum Kinetics</p> <p>Don E. Willcox, Lawrence Berkeley National Laboratory, USA Sherwood Richers, University of Tennessee, Knoxville, USA</p> <p>Neutron star mergers and core collapse supernovae are extreme multiphysics events with heavy element production largely dependent on the amount of electron flavor content in the event. The importance of nucleosynthetic outcomes in these events has raised neutrino flavor transformations to an area of active research, particularly focused on determining the effects of fast growing neutrino flavor instabilities arising from neutrino-neutrino interactions. Neutrino quantum kinetics is a challenge to research, however, since simulation codes must resolve small length, time, and angular scales in the neutrino distribution in order to accurately compute the neutrino self-interaction potential. Most approaches thus make significant approximations. We have advanced the capabilities of this research field by developing Emu, an open-source particle-in-cell simulation code solving the neutrino quantum kinetics equations with arbitrary angular resolution in three dimensions. Emu achieves this by representing the neutrino distribution with a set of computational particles, each with unique position, momentum, and quantum state. Emu's C++ kernels for evolving each particle's quantum state are symbolically generated from the quantum kinetics equations using Sympy. Emu is also built on top of AMReX, a scalable computational framework with domain-distributed particle-mesh routines offering performance portability on CPUs and GPUs. Emu thus enables detailed multidimensional studies of the neutrino fast flavor instability, resolved in space, angle, and time. This poster will present Emu's design and performance on modern supercomputing platforms before pointing to new opportunities Emu enables for studying the multidimensional fast flavor instability and its astrophysical implications.</p>