ASTRONUM 2018
ORAL ABSTRACTS

Bacchini, Fabio	***Advanced Algorithms for Special and General Relativistic Particle Simulations*** Fabio Bacchini, KU Leuven, Belgium Bart Ripperda, KU Leuven, Belgium Alex Chen, Princeton University, USA Lorenzo Sironi, Columbia University, USA Relativistic particle methods are an extremely powerful tool for modeling astrophysical plasma phenomena. In the special relativistic limit, kinetic Particle-in-Cell (PiC) codes are a widely employed mean of obtaining insights on the microscopic dynamics characterizing high-energy processes such as magnetic reconnection and beam-plasma instabilities. Here, we present the latest advances on exactly energy-conserving, fully implicit methods for PiC simulations of relativistic plasmas. We review the numerical details of the implementation of such methods in high-performance, parallelized frameworks and provide proofs of the quality of the obtained results. Furthermore, we extend the numerical techniques to handle curved spacetimes, allowing for the simulation of charged, massive particles around black holes and neutron stars. With the obtained tools, we foresee a direct extension of the special relativistic PiC method to general relativistic simulations of kinetic processes.
Bisikalo, Dmitry	***Influence of Stellar Radiation on the Flow Structure in Envelope of Hot Jupiter*** Dmitry Bisikalo, Alexander Cherenkov Institute of astronomy of the Russian Academy of Sciences Hot Jupiter exoplanets are subjected to extreme radiation of their parent stars. Photo- metric observations of the hot Jupiter transits with HST/STIS detected strong absorption in Lyman-alpha line, thus indicating the existence of an extended hydrogen envelope beyond the Roche lobe. Gas dynamic and MHD modeling shows that, if the dynamical pressure of the stellar-wind is high enough to stop the outflow from the vicinity of the inner Lagrangian point, a quasi-closed non-spherical envelope, bounded by the bow-shock of a complex shape, forms in the system. In this report we discuss the impact of stellar radiation pressure in Lyman-alpha line on gasdynamics in envelope of hot-Jupiter HD209458b, orbiting its solar-like type star. Simulations show that for HD 209458 b radiation pressure acts only on thin ”substellar” layer, locally changing dynamics, but total impulse in this absorbed line is not enough to have significant impact on gasdynamics, and therefore, evolution of atmosphere of this hot Jupiter. To have significant observable effect due to radiation pressure it is required to increase intensity of Lyman-alpha line by two order of magnitude.
Calder, Alan	***Thermonuclear (Type Ia) Supernovae and Progenitor Evolution*** Alan C. Calder, Stony Brook University, USA Donald E. Willcox, Stony Brook University, USA Dean M. Townsley, University of Alabama, USA Thermonuclear (type Ia) supernovae are bright stellar explosions with the unique property that the light curves can be standardized, allowing them to be used as distance indicators for cosmological studies. Many fundamental questions about these events remain, however. We provide a critique of our present understanding of these and present results of simulations assuming the single-degenerate progenitor model consisting of a white dwarf that has gained mass from a stellar companion. We present results from full three-dimensional simulations of convection with weak reactions comprising the A=23 Urca process in the progenitor white dwarf.

Gaburro, Elena	***Well Balanced Arbitrary-Lagrangian-Eulerian Finite Volume Schemes on Moving Nonconforming Meshes for the Euler Equations of Gasdynamics with Gravity*** Elena Gaburro, University of Trento, Italy Michael Dumbser, University of Trento, Italy Manuel J. Castro, University of Malaga, Spain In this work we present a novel second order accurate well balanced Arbitrary-Lagrangian-Eulerian (ALE) finite volume scheme on moving nonconforming meshes for the Euler equations of compressible gasdynamics with gravity in cylindrical coordinates. The main feature of the proposed algorithm is the capability of preserving many of the physical properties of the system exactly also on the discrete level: besides being conservative for mass, momentum and total energy, also any known steady equilibrium between pressure gradient, centrifugal force and gravity force can be exactly maintained up to machine precision. Perturbations around such equilibrium solutions are resolved with high accuracy and with minimal dissipation on moving contact discontinuities even for very long computational times. This is achieved by the novel combination of well balanced path-conservative finite volume schemes, that are expressly designed to deal with source terms written via nonconservative products, with ALE schemes on moving grids, which exhibit only very little numerical dissipation on moving contact waves. In particular, we have formulated a new HLL-type and a novel Osher-type flux that are both able to guarantee the well balancing in a gas cloud rotating around a central object. Moreover, to maintain a high level of quality of the moving mesh, we have adopted a nonconforming treatment of the sliding interfaces that appear due to the differential rotation. A large set of numerical tests has been carried out in order to check the accuracy of the method close and far away from the equilibrium, both, in one and two space dimensions. Finally, nontrivial test problems in a rotating Keplerian gas disk shows the greatly reduced dissipation and the significant improvements of the new scheme on moving contact discontinuities compared to classical non well balanced Eulerian methods on fixed grids.
Grosheintz, Luc	***High-order Well-balanced Finite Volume Methods for Euler Equations with Gravity*** Luc Grosheintz, Seminar of Applied Mathematics, ETH Zurich Hydrostatic equilibria are a common class of stationary solutions to the Euler equations with gravity. It's the force-balance of pressure and gravity. While the force-balance may be exact on the continuous level, this is typically no longer the case for Finite Volume Methods (FVM) at the discrete level. We will present a novel high-order FVM which maintains hydrostatic equilbria to machine precision. Further, we will present out progress towards balancing non-stationary equilibria. Examples of non-stationary equilibria are rotating fluids where pressure gradient, gravity and inertial force balance. We've implemented well-balanced schemes for structured and unstructured grids. We will show astrophysically relevant examples using these novel schemes.
Koshkarov, Oleksandr	***A Framework for Microscopic/Macroscopic Simulations of Magnetized Plasmas*** Gian Luca Delzanno, Los Alamos National Laboratory, USA Vadim Roytershteyn, Space Science Institute, USA Gianmarco Manzini, Los Alamos National Laboratory, USA Many problems in plasma physics require the solution of the Vlasov-Maxwell (VM) or Vlasov-Boltzmann equations. These equations are extremely hard to solve numerically because of their high dimensionality, nonlinearities and the huge spatial and temporal scale separation. While several reduced methods have been developed in certain limits, a comprehensive approach capable of obtaining accurate solutions in all parameters regimes remains elusive. We will present a spectral method for the VM equations based on a decomposition of the plasma phase-space density in Hermite or Legendre modes. Its most important feature is that, with a suitable spectral basis, the low-order moments correspond to the typical fluid moments (mass, momentum, energy) of the plasma, while the kinetic/microscopic physics can be retained by adding more moments. With the 'built-in' fluid/kinetic coupling, the method might offer an optimal way to perform accurate simulations of macroscopic phenomena including microscopic physics. The method features favorable numerical properties, such as spectral convergence and exact conservation laws in the limit of finite time step. A comparison between the Particle-In-Cell (PIC) and the spectral method on standard electrostatic test problems shows that the spectral method can be orders of magnitude faster/more accurate than PIC for some problems. Furthermore, we have recently developed a hybrid simulation approach that couples the spectral method with a PIC technique. The goal is to combine the accuracy typical of spectral methods, with the flexibility of PIC in dealing with complex distribution functions that might otherwise require a large number of moments for convergence. The application of the spectral/PIC method to the problem of the interaction of a weak beam with a background plasma will be discussed, showing the potential of the hybrid method in terms of computational efficiency and accuracy.

Li, Shengtai	***Numerical Simulations for Laboratory Astrophysics using FLASH*** Shengtai Li, Theoretical Division, Los Alamos National Laboratory, USA Hui Li, Theoretical Division, Los Alamos National Laboratory, USA Kirk A. Flippo, Physics Division, Los Alamos National Laboratory, USA In this talk, we will present results of numerical simulations for different laboratory astrophysics experiments on Omega laser facility. The FLASH code developed at Flash Center of University of Chicago will be used in all the simulations. The FLASH code has been extended with numerous capabilities to allow it to simulate laser-driven High Energy Density Physics (HEDP) experiments. We will show results of generation of hydrodynamics instability and magnetic field via Biemann battery term, and how the magnetic fields get amplified by the turbulence-dynamo effect. The research is supported by the Los Alamos Laboratory Directed Research and Development (LDRD) fund.
O'Shea, Brian	***Modeling the Milky Way: Challenges and Opportunities*** Brian O'Shea, Michigan State University I provide an overview of the current state-of-the-art in cosmological simulations of galaxy formation, focusing on the largest and most physically accurate simulations and what they can tell us about galaxy formation and evolution. I will also critically examine the future of galaxy formation simulations, including missing physics, numerical challenges, and opportunities for improved modeling.
Ripperda, Bart	***Resistivity in General Relativistic Magnetohydrodynamics: An Application to Relativistic Reconnection and Particle Acceleration*** Bart Ripperda, Centre for mathematical Plasma Astrophysics, Belgium Lorenzo Sironi, Department of Astronomy, Columbia University, USA Oliver Porth, Institut fur Theoretische Physik, Germany Rony Keppens, Centre for mathematical Plasma Astrophysics, Belgium Resistivity plays a crucial role in the formation of current sheets, magnetic reconnection and the growth of plasmoids in relativistic magnetohydrodynamics (MHD). We have recently included resistivity in the general relativistic MHD (GRMHD) code BHAC. The code has also been improved with adaptive mesh refinement in combination with flux constrained transport to keep the field divergence-free. We present tests of the newly implemented methods in both special relativistic and general relativistic cases. To analyse particle acceleration, we adapted the code to evolve charged test particles according to the Lorentz force. We applied the resistive code to coalescing magnetic islands causing reconnection in magnetized plasma in 2D flat slabs in Minkowski spacetime. The low resistivity is resolved with very high accuracy due to the extreme resolutions obtained with adaptive mesh refinement. We applied both uniform resistivity and anomalous, spatiotemporally dependent resistivity based on the current density. We found that the plasmoid instability is triggered for Lundquist numbers of 20000 where it is not for Lundquist numbers of 10000. However, for anomalous resistivity with a background Lundquist number of 10000 and an enhanced resistivity in the current sheet, we find plasmoid formation. In all three setups we evolve charged test particles to determine acceleration sites and energy distributions. We find that electrons accelerate to non-thermal energies in the thin current sheets in all cases, and in the formed plasmoids in the cases liable to the plasmoid instability. The maximum Lorentz factor for the particles depends on the resistivity.

Zank, Gary	***Theory and Transport of Nearly Incompressible Magnetohydrodynamic Turbulence in the Solar Corona*** G.P. Zank, University of Alabama in Huntsville, USA L. Ashikhari, University of Alabama in Huntsville, USA P. Hunana, University of Alabama in Huntsville, USA S.K. Tiwari, Lockheed Martin, USA R. Moore, University of Alabama in Huntsville, USA D. Shiota, Nagoya University, Japan R. Bruno, INAF-IAPS-Rome, Italy D. Telloni, INAF-Torinio, Italy A new model describing the transport and evolution of turbulence in the quiet solar corona is described. In the low plasma beta environment, transverse photospheric convective fluid motions drive predominantly quasi-2D (non-propagating) turbulence in the mixed polarity “magnetic carpet,” together with a minority slab (Alfvenic) component. We use a simplified sub-Alfvenic flow velocity profile to solve transport equations describing the evolution and dissipation of turbulence from 1 - 15 Rs (including the Alfven surface). Typical coronal base parameters are used, although one model uses correlation lengths derived observationally by Abramenko et al. 2013, and the other assumes values 10 times larger. The model predicts that 1) the majority quasi-2D turbulence evolves from a balanced state at the coronal base to an imbalanced state, with outward fluctuations dominating, at and beyond the Alfven surface, i.e., inward turbulent fluctuations are dissipated preferentially; 2) the initially imbalanced slab component remains imbalanced throughout the solar corona, being dominated by outwardly propagating Alfven waves, and wave reflection is weak; 3) quasi-2D turbulence becomes increasingly magnetized, and beyond ~6 Rs, the kinetic energy is mainly in slab fluctuations; 4) there is no accumulation of inward energy at the Alfven surface; 5) inertial range quasi-2D rather than slab fluctuations are preferentially dissipated within ~3 Rs, and 6) turbulent dissipation of quasi-2D fluctuations is sufficient to heat the corona to temperatures ~2 million degrees K within 2 Rs, consistent with observations that suggest the fast solar wind is accelerated most efficiently between ~2 - 4 Rs.
Zingale, Michael	***Modeling Type Ia Supernovae and X-ray Bursts*** Michael Zingale, Stony Brook University, USA We discuss the progress made in modeling Type Ia supernovae and X-ray bursts and what challenges remain. We show our current progress on both of these events, looking at a variety of different progenitor models for Type Ia supernovae and the burning dynamics in X-ray bursts, and outline our future goals. Numerical challenges will be discussed along with some new algorithmic ideas to overcome these issues.