HEDLA 2012

9th International Conference on High Energy Density Laboratory Astrophysics
Tallahassee, Florida, April 30 – May 4, 2012

The HEDLA 2012 conference is jointly sponsored by DOE National Nuclear Security Administration, Commissariat a l’Energie Atomique, the Florida State University, and the Tourism Development Department of Leon County.

United States (US)	1,992
France (FR)	335
United Kingdom (GB)	214
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Mexico (MX)	7
Ireland (IE)	6
Belgium (BE)	6
Taiwan (TW)	6
Cameroon (CM)	5
Romania (RO)	3
Brazil (BR)	2
Ukraine (UA)	2
Congo, The Democratic Republic of the (CD)	2
Serbia (RS)	2
Australia (AU)	2
Nepal (NP)	2
Saudi Arabia (SA)	2
Czech Republic (CZ)	2
Finland (FI)	2
Sweden (SE)	2
Hungary (HU)	2
Chile (CL)	2
Colombia (CO)	2
Belarus (BY)	1
Norway (NO)	1
Denmark (DK)	1
South Africa (ZA)	1
Kazakstan (KZ)	1
Croatia (HR)	1
Philippines (PH)	1
Egypt (EG)	1
Hong Kong (HK)	1
United Arab Emirates (AE)	1
Thailand (TH)	1
Nigeria (NG)	1
Slovakia (SK)	1
Europe (EU)	1
Uzbekistan (UZ)	1
Greece (GR)	1
Austria (AT)	1

Transportation

If you are renting a car, there is a five story parking garage attached to the Conference Center and available free of charge to the conference participants.

Shuttle Bus Schedule

Monday, April 30		
7:00 am	from hotels	to Conference Center
7:30 am	from hotels	to Conference Center
6:10 pm	from Conference Center	to hotels

Tuesday, May 1		
7:00 am	from hotels	to Conference Center
7:30 am	from hotels	to Conference Center
6:10 pm	from Conference Center	to hotels

Wednesday, May 2		
7:00 am	from hotels	to Conference Center
7:30 am	from hotels	to Conference Center
12:45 pm	from Conference Center	to hotels
2:30 pm	from hotels	to the Wakulla Springs SP
5:30 pm	from the Wakulla Springs SP	to hotels (return around 6:00 p.m.)

Thursday, May 3		
7:00 am	from hotels	to Conference Center
7:30 am	from hotels	to Conference Center
6:10 pm	from Conference Center	to hotels

Friday, May 4		
6:30 am	from hotels	to Conference Center
7:00 am	from hotels	to Conference Center
7:30 am	from hotels	to Conference Center
8:00 am	from hotels	to Conference Center
3:55 pm	from Conference Center	to hotels
4:25 pm	from Conference Center	to hotels
4:55 pm	from Conference Center	to hotels

- The number of seats per bus is limited to 56.
- If you need special arrangements for your departure, please contact conference coordinators at the conference desk.

Conference Program

Sunday, April 29

5:45 - 8:00 pm	**Registration**
6:00 - 8:00 pm	**Welcome Reception**

Monday, April 30

7:00 - 7:30 am	Bus departs
7:30 - 8:20 am	Breakfast (at Conference Center, included in registration), registration
8:20 - 8:30 am	Opening remarks
	Session 1A1: Laboratory Experiments I: Design, diagnostics, scaling
8:30 - 9:10 am	**Radu Presura** (University of Nevada, Reno) Lab diagnostics primer for astronomers [40]
9:10 - 9:30 am	**Nathan Kugland** (LLNL) Proton imaging of collisionless shock experiments at OMEGA EP [20]
9:30 - 9:45 am	**Carlos Di Stefano** (University of Michigan) Proton-diagnostic performance in laser-driven hydrodynamics experiments [15]
9:45 - 10:00 am	**Kristopher Yirak** (LANL) Mach stem hysteresis: Experiments addressing a novel explanation of clumpy astrophysical jet emission [15]
10:00 - 10:30 am	**Paul Drake** (University of Michigan) HEDLA 1996 vs. 2012 [30]
10:30 - 12:30 am	Break and poster viewing [120]
12:30 - 1:45 pm	Lunch (at Conference Center, included in registration) [75]
	Session 1P1: Astrophysical Jets & Disks I. AGN, black hole, protostellar
1:45 - 2:25 pm	**Mario Livio** (Space Telescope Science Institute) Astrophysical jets [40]
2:25 - 2:45 pm	**Debra Shepherd** (National Radio Astronomy Observatory) ALMA and JVLA: Insight into astrophysical jets [20]
2:45 - 3:00 pm	**Francisco Suzuki-Vidal** (Imperial College, London, UK) Interaction of radiatively cooled plasma jets with collimated, supersonic gas flows[15]
3:00 - 3:15 pm	**Andrea Ciardi** (Observatoire de Paris) Outflow collimation by a poloidal magnetic field [15]
3:15 - 3:30 pm	**Anton Dorodnitsyn** (NASA GSFC and the University of Maryland) How to hide a supermassive black hole: AGN obscuration through dusty infrared dominated flows [15]
3:30 - 4:15 pm	Break and poster viewing [45]
	Session 1P2: Plasma Physics I. Collisionless shocks, magnetic reconnection, ultrastrong fields, turbulence, instabilitiess
4:15 - 4:45 pm	**Hantao Ji** (Princeton Plasma Physics Laboratory) Laboratory studies of magnetic reconnection [30]
4:45 - 5:15 pm	**Anatoly Spitkovsky** (Princeton University) Astrophysical collisonless shocks
5:15 - 5:30 pm	**Yasuhiro Kuramitsu** (Osaka University, Japan) Electron scale magnetic reconnection in a laser produced plasma [15]
5:30 - 5:45 pm	**Jiayong Zhong** (Key Laboratory of Optical Astronomy, Beijing, China) Spatial and temporal evolution of extremely strongly laser driven magnetic reconnection [15]
5:45 - 6:00 pm	**Yutong Li** (National Laboratory of Condensed Matter Physics, Beijing, China) Collisionless shockwaves formed by counter-streaming laser-produced plasmas [15]
6:10 pm	Bus returns

Tuesday, May 1

7:00 - 7:30 am	Bus departs
7:30 - 8:20 am	Breakfast (at Conference Center, included in registration), registration
8:20 - 8:30 am	Announcements
	Session 2A1: Supernovae I. SNe, SNRs, GRBs, exploding systems
8:30 - 9:10 am	**Robert Kirshner** (Harvard University) Supernovae: the gift that keeps on giving [40]
9:10 - 9:30 am	**Alexis Casner** (CEA, France) Designs and implementation plan for highly nonlinear ablative Rayleigh-Taylor Instability experiments on the National Ignition Facility [20]
9:30 - 9:50 am	**Vladimir Smalyuk** (University of Rochester) Laboratory basic science, hydrodynamic growth experiments on OMEGA [20]
9:50 - 10:05 am	**Desmond John Hillier** (University of Pittsburgh) Unlocking the secrets of supernovae through their spectra [15]
10:05 - 10:45 am	Break and poster viewing [40]
	Session 2A2: Solar and Stellar Physics I. Evolution, structure, opacities, radiative transfer, white dwarfs, neutron stars
10:45 - 11:25 am	**Michael Wiescher** (University of Notre Dame) The physics of reaction rates in stellar environments [40]
11:25 - 11:40 am	**Irina Sagert** (Michigan State University) Strange matter in neutron stars and core-collapse supernovae [15]
11:40 - 11:55 pm	**James Bailey** (SNL) ZAPP: The Z astrophysical plasma properties collaboration [15]
11:55 - 12:15 pm	**Ross Falcon** (University of Texas at Austin) An experimental platform for creating white dwarf photospheres in the laboratory[20]
12:15 - 12:30 pm	**Quan-Li Dong** (National Laboratory of Condensed Matter Physics, Beijing, China) Observations of anomalous plasmoid ejection, plasma jets and electron diffusion regions of magnetic reconnections in laser-plasma experiments [15]
12:30 - 1:45 pm	Lunch (at Conference Center, included in registration) [75]
	Session 2P1: Computing I. Astrophysical simulations, design of experiments, validation studies
1:45 - 2:25 pm	**Jim Stone** (Princeton University) Challenges of modeling astrophysical MHD [40]
2:25 - 2:45 pm	**Frederico Fiuza** (Instituto Superior Tecnico, Lisbon, Portugal) Full-scale modeling of Weibel mediated collisionless shocks in laboratory scenarios[20]
2:45 - 3:00 pm	**Bruce Fryxell** (University of Michigan) Collaborative comparison of high-energy-density physics codes [15]
3:00 - 3:15 pm	**Timothy Handy** (Florida State University) Computer experiments for supersonic turbulent flows in high-energy density plasmas [15]
3:15 - 3:30 pm	**Hanbyul Jang** (Chungnam National University, Korea) A relativistic magnetohydrodynamic code based on upwind scheme [15]
3:30 - 4:15 am	Break and poster viewing [45]
	Session 2P2: Warm Dense Matter: Planetary interiors, EOS, magnetic fields in giant planets, exoplanets
4:15 - 4:55 pm	**Peter Celliers** (LLNL) Experiments to probe warm dense matter conditions for planetary science [40]
4:55 - 5:15 pm	**Burkhard Militzer** (University of California, Berkeley) Phase separation in giant planet interiors and novel first-principles simulation of plasmas [20]
5:15-5:30 pm	**Francois Soubiran** (ENS Lyon, France) Thermodynamical and transport properties of dense H-He mixtures [15]
5:30-5:45 pm	**Manuel Cotelo** (Instituto de Fusion Nuclear, Madrid, Spain) Improvements in equation of state and opacities for warm dense matter [15]
5:45 - 6:00 pm	**Stanley Davis** (University Bordeaux, France) Numerical simulations of electron heating during energy transfer in a laser driven collisionless shock [15]
6:10 pm	Bus returns

Wednesday, May 2	
7:00 - 7:30 am	Bus departs
7:30 - 8:20 am	Breakfast (at Conference Center, included in registration), registration
8:20 - 8:30 am	Announcements
	Session 3A1: Radiative Hydrodynamics I. Radiative shocks, radiatively driven instabilities, molecular clouds, stellar winds
8:30 - 9:10 am	**Roberto Mancini** (University of Nevada, Reno) Laboratory photoionized plasma experiments relevant for astrophysics [40]
9:10 - 9:30 am	**Edward Hill** (Imperial College, London, UK) Alternative methods of producing photoionised plasmas in the laboratory [20]
9:30 - 9:45 am	**Carolyn Kuranz** (University of Michigan) The evolution of a radiative shock system on the OMEGA Laser [15]
9:45 - 10:00 am	**Siegfried Glenzer** (LLNL) Expanding shock waves from 100 Gbar implosions on the National Ignition Facility[15]
10:00 - 10:15 am	**Jim Ferguson** (Texas A&M University) Asymptotic accuracy of the equilibrium-diffusion approximation [15]
10:15 - 10:45 am	Break [30]
	Session 3A2: Astrophysical dust & magnetized HEDLA
10:45 - 11:15 am	**Farid Salama** (NASA Ames) Interstellar dust - a review [40]
11:15 - 11:35 am	**Dmitri Ryutov** (LLNL) Basic scalings for collisionless shock experiments [20]
11:35 - 12:05 pm	**Sergey Lebedev** (Imperial College, London, UK) Magnetized jet experiments and radiative shocks driven by pulsed power
12:05 - 12:20 pm	**Jeffrey Bonde** (University of California, Los Angeles) Collisionless interaction between axial plasma jet and ambient, magnetized plasma measured using laser-induced fluorescence [15]
12:20 - 12:35 pm	**Adam Frank** (University of Rochester) The formation of magnetized molecular clouds: New results and experimental possibilities [15]
12:45 pm	Bus returns
	AFTERNOON FREE

Wakulla Springs Trip

We have organized a bus (35 seats) to take attendees to the nearby state park Wednesday afternoon. The bus will collect passengers from their hotels around 2:30 pm and will arrive back in Tallahassee around 6:00 pm. Seating is first-come, first-served so please contact the receptionists if you'd like to attend.

The Park offers 30-45 minutes boat tours (and we may try to arrange for a special glass bottom tour) on the Wakulla River, known for its pristine character. The boat tours are $8 per person.

The Wakulla Spring waters are truly crystal clear, and with a dry season ahead of us viewing and taking fabulous photos of trees, plants, fish, birds, and alligators is (almost) certain. Swimming is also quite popular especially on a hot day, although water is a bit on a chilly side (especially considering the location is in subtropics). There is also a hiking trail about 1 km long providing for a scenic walk.

Visit www.hedla2012.org or www.floridastateparks.org/wakullasprings for more information about the park.

Thursday, May 3

7:00 - 7:30 am	Bus departs
7:30 - 8:20 am	Breakfast (at Conference Center, included in registration), registration
8:20 - 8:30 am	Announcements
	Session 4A1: Plasma Physics II
8:30 - 9:00 am	**Jungyeon Cho** (Chungnam National University, Korea) Magnetized turbulence in astrophysical fluids [30]
9:00 - 9:20 am	**Yuichi Sakawa** (Osaka University, Japan) Laboratory experiments to study collisionless shocks [20]
9:20 - 9:40 am	**Hye-Sook Park** (LLNL) Astrophysical collisionless shocks in the laboratory [20]
9:40 - 9:55 am	**Dongsu Ryu** (Chungnam National University, Korea) A simulation study of intracluster turbulence [15]
9:55 - 10:10 am	**Mikhail Medvedev** (University of Kansas) Theory and numerical modeling of radiation from sub-Larmor-scale magnetic turbulence [15]
10:10 - 11:00 am	Break and poster viewing [50]
	Session 4A2: Supernovae II
11:00 - 11:40 am	**Sergey Blinnikov** (ITEP, Moscow, Russia) Radiation hydrodynamics of supernova shock breakouts
11:40 - 11:55 am	**Tomasz Plewa** (Florida State University) Diverging core-collapse supernova experiments on NIF [15]
11:55 - 12:10 am	**Vikram Dwarkadas** (University of Chicago) The acceleration and escape of particles in young supernova remnants [15]
12:10 - 12:25 am	**Alexei Poludnenko** (Naval Research Laboratory) Spontaneous deflagration-to-detonation transition in thermonuclear supernovae [15]
12:30 - 1:45 pm	Lunch (at Conference Center, included in registration) [75]
	Session 4P1: Solar and Stellar Physics II
1:45 - 2:25 pm	**Sarbani Basu** (Yale University) Confronting stellar structure theory with asteroseismic data [40]
2:25 - 2:45 pm	**Eve Stenson** (Caltech) The dynamics of arched, plasma-filled magnetic flux tubes [20]
2:45 - 3:00 pm	**Shule Li** (University of Rochester) Clumps with self-contained magnetic field and their interaction with shocks [15]
3:00 - 3:15 pm	**Guy Malamud** (University of Michigan) On the possibility of a two-dimensional, multimode RM experiment on EP [15]
3:15 - 4:15 pm	Break and poster viewing [60]
	Session 4P2: Astrophysical Jets and Disks II. Laboratory Experiments
4:15 - 4:55 pm	**Jonathan Ferreira** (Universite Joseph Fourier, Grenoble, France) What does it take to launch jets from accretion discs? [40]
4:55 - 5:10 pm	**Martin Huarte-Espinosa** (University of Rochester) Comparing Poynting flux dominated magnetic towers with kinetic-energy dominated jets [15]
5:10 - 5:25 pm	**Edison Liang** (Rice University) Magnetic field generation and particle acceleration in relativistic shear boundary layer [15]
5:25 - 5:45 pm	**Auna Moser** (Caltech) Laboratory observations of magnetic reconnection resulting from multiscale instability cascade [20]
5:45 - 6:00 pm	**Taichi Morita** (Osaka University, Japan) Interaction of high Mach-number shocks in laser-produced plasmas [15]
6:10 pm	Bus returns

Friday, May 4

7:00 - 7:30 am	Bus departs
7:30 - 8:20 am	Breakfast (at Conference Center, included in registration), registration
8:20 - 8:30 am	Announcements
	Session 5A1: Laboratory Experiments II
8:30 - 9:10 am	**Serge Bouquet** (CEA, France) Scaling astrophysical radiation hydrodynamics for the laboratory [40]
9:10 - 9:30 am	**Will Fox** (University of New Hampshire) Fast magnetic reconnection in high-energy-density laser-produced plasmas [20]
9:30 - 9:45 am	**Yong-Joo Rhee** (Korea Atomic Energy Research Institute, Korea) Laser-produced high density plasmas [15]
9:45 - 10:00 am	**Kirk Flippo** (LANL) Investigating mix in colliding-shock experiments [15]
10:00 - 10:15 am	**Matteo Bocchi** (Imperial College, London) Numerical simulations of Z-Pinch experiments to create supersonic differentially rotating plasma flows [15]
10:15 - 11:00 am	Break and poster viewing [45]
	Session 5A2: Computing II
11:00 - 11:40 am	**Bernie Wilde** (LANL) The art of designing and fielding relevant HEDP experiments
11:40 - 12:00 am	**Milad Fatenejad** (University of Chicago) FLASH simulations of experiments to explore the generation of cosmological magnetic fields [20]
12:00 - 12:15 pm	**James Glimm** (Stony Brook University) Turbulent mixing at the high Re limit: V&V/UQ [15]
12:15 - 12:30 am	**J. Tiberius Moran-Lopez** (University of Michigan) A weighted essentially nonoscillatory implementation of a Reynolds-averaged Navier-Stokes model for Richtmyer-Meshkov instability-induced mixing [15]
12:30 - 1:45 pm	Lunch (at Conference Center, included in registration) [75]
	Session 5P1: Radiative Hydrodynamics II
1:45 - 2:05 pm	**Jonathan Mackey** (Argelander Institut fuer Astronomie, Bonn, Germany) Effects of magnetic fields on photoionised pillars of dense gas [20]
2:05 - 2:45 pm	**Berenice Loupias** (CEA, France) Theory and experiments of accretion processes in cataclysmic variables [40]
2:45 - 3:00 pm	**Christine Krauland** (University of Michigan) Reverse radiative shock laser experiments relevant to accreting stream-disk impact in interacting binaries [15]
3:00 - 3:15 pm	**Emeric Falize** (CEA, France) Recent advances in the experimental simulation of X-ray binary stars accretion shocks [15]
3:15 - 3:30 pm	**Bart van der Holst** (University of Michigan) Simulating the long-term evolution of radiative shocks in shock tubes [15]
3:30 - 3:45 pm	**Bruce Remington** (LLNL) Conference Summary [15]
3:55 pm	Bus returns

HEDLA 2012 Conference Program

Lab diagnostics primer for astronomers

Radu Presura[1]

[1]University of Nevada, Reno

Abstract

In the laboratory, high energy density conditions are created by depositing energy over durations shorter than it takes the sample to disintegrate. The systems thus produced are highly inhomogeneous, often anisotropic, short lived, evolving so rapidly that sometimes they do not reach equilibrium during the experiment. These extreme conditions have stimulated experimentalists and diagnosticians to create potent diagnostics techniques capable to characterize the experimental systems in detail and to glean accurate data necessary for understanding astrophysical objects and phenomena. This talk will briefly review elegant and successful techniques most commonly used in the laboratory. As the passive diagnostics are familiar to astronomers, the focus will be placed on active techniques, which employ external, well controlled radiation or particle beams to probe a high energy density sample. The review will include the physical principles and the applicability conditions for these diagnostics, as well as examples of implementation and illustrating results.

Proton imaging of collisionless shock experiments at OMEGA EP

N. L. Kugland[1]

[1]Lawrence Livermore National Laboratory, Livermore, CA, USA

Abstract

Astrophysical collisionless shocks may play a role in diverse phenomena such as high-energy cosmic ray acceleration and the ubiquitous magnetization of the universe. These shocks are predicted to coalesce from collective plasma effects mediated by electric and magnetic fields. However, the precise mechanisms by which electric and magnetic fields contribute to collisionless shock formation and associated astrophysical phenomena are still largely unknown. Our collaboration (Astrophysical Collisionless Shocks with Lasers, or ASCEL) is studying the signatures of collisionless shock formation in the laboratory. One of our approaches is to use short-pulse laser generated proton imaging at the large-scale OMEGA EP laser facility. Two opposing CH_2 disks spaced 8 mm apart were driven with 2200 J (per target) of 351 nm light over 3 ns to create a millimeter-scale interaction region of two overlapping, high-velocity (1000 km/s) plasmas with moderately low ion densities estimated to be in the range of 10^{18}-10^{19} cm^{-3}. Under these conditions the inter-flow collisional mean free path exceeds the size of the system, a regime that is appropriate for collisionless shock formation. Two 10 ps, 250 J short-pulse laser beams were used to proton radiograph the long pulse plasma from orthogonal views. Proton images reveal electromagnetic field structures that form and then change shape dramatically over several ns. Spherically symmetric structures, prolate "filaments" and oblate "pancakes" are observed. These structures vary in size over a wide range of spatial scales from tens of μm to several mm. Field strengths within the plasma are estimated using a new first-principles analytic "toolkit" that we have developed to relate electric and magnetic field structures to their proton-beam images.

Prepared by LLNL under Contract DE-AC52-07NA27344.

Proton-diagnostic performance in laser-driven hydrodynamics experiments

C. Di Stefano[1], C.C. Kuranz[1], R P. Drake[1], M.J. Grosskopf[1], C.M. Krauland[1], D.C. Marion[1], S.R. Klein[1], B. Fryxell[1], P.M. Nilson[2], and T. Plewa[3]

[1]University of Michigan
[2]University of Rochester
[3]Florida State University

Abstract

Magnetic fields are often generated in high-energy-density experiments, and proton radiography is an important technique for detecting the effects of such fields. Target-normal sheath acceleration (TNSA) is a useful method for generating the necessary proton beams, but its performance is very sensitive to laser-chamber conditions, the exact effects of which are not completely understood. This presentation describes the behavior of the TNSA diagnostic in an experiment performed on the OMEGA-EP laser, attempting to detect self-generated magnetic fields at a blast-wave-driven, Rayleigh-Taylor(RT)-unstable interface. In the experiment, laser energy is used to create a planar blast wave in a plastic disk; the blast wave then crosses the interface between the disk and a lower-density foam, inducing the RT instability. An initial perturbation, to seed the instability, is machined at the interface. This system differ significantly from typical experiments employing the TNSA diagnostic, and it was found that some aspects of the experimental geometry, combined with the long time scale on which this hydrodynamic experiment evolves, greatly affected the quality of the corresponding proton images. Connections between these data and relevant features of the setup will be explored.

This work is funded by the NNSA-DS and SC-OFES Joint Program in HEDLP, by the NLUF in NNSA-DS and by the PSAAP in NNSA-ASC. The corresponding grant numbers are DE- FG52-09NA29548, DE-FG52-09NA29034, and DE-FC52-08NA28616.

Mach stem hysteresis: experiments addressing a novel explanation of clumpy astrophysical jet emission

Kristopher Yirak[1], Pat Hartigan[2], John Foster[3], Bernhard Wilde[1],
Adam Frank[4], Paula Rosen[3], Melissa Douglas[1], Reny Paguio[5],
David Farley[6], and David Martinez[6]

[1]Los Alamos National Laboratory (LANL), Los Alamos, NM
[2]Rice University, Houston, TX
[3]Atomic Weapons Establishment (AWE), Aldermaston, UK
[4]University of Rochester, Rochester, NY
[5]General Atomics (GA), San Diego, CA
[6]Lawrence Livermore National Laboratory (LLNL), Livermore, CA

Abstract

Recent epochal observations using the Hubble Space Telescope (Hartigan et al., 2011) reveal localized emission features which may be followed over nearly 15 years. Some of these features are believed to be dense *clumps* which emit due to a velocity dispersion with their fellows or the background. We propose that others, however, are better described as the result of intersecting bow shocks. Shock theory indicates that if the angle between two intersecting bows is above a certain value, a third shock (*Mach stem*) will form and grow. The Mach stem will form perpendicular to the direction of flow, meaning incoming particles will see a normal shock instead of an oblique one, which could lead to brighter emission at this location. We have carried out experiments aimed at understanding the formation, growth, and destruction of such Mach stems. We present our results to date, as well as our new program to push the experiments into the radiative regime.

Astrophysical jets

Mario Livio[1]

[1]Space Telescope Science Institute

Abstract

I will review the observations of jets in a variety of astrophysical objects, and will attempt to place constraints on the mechanisms of jet acceleration and collimation, assuming that the process of jet formation is universal.

What ALMA will do for jet observations

Debra Shepherd[1]

[1]National Radio Astronomy Observatory

Abstract

Observations using the Atacama Large Millimeter Array (ALMA) and the Jansky Very Large Array (JVLA) will address gaps in our understanding of astrophysical disks, jets and outflows from young stellar objects, evolved stars and black holes. ALMA JVLA will achieve high resolution to map small-scale structure in jets and accretion disks allowing us to explore how material is lifted off the disk and collimated into ionized jets. For example, the ability to observe hydrogen recombination lines from centimeter to millimeter wavelengths will provide a clear understanding of the kinematic and dynamical properties of jets and ionized outflows that are critical to understanding magnetic field collimation. ALMA will also recover even the most extended emission in large-scale out-flowing molecular material, allowing a detailed study of hydrodynamic mixing and dust formation. In this talk, I will highlight those features of ALMA JVLA that will contribute to our understanding of astrophysical jets and disks and discuss some of the limitations of the observations that will make interpretation challenging.

Interaction of radiatively cooled plasma jets with collimated, supersonic gas flows

F. Suzuki-Vidal[1], S.V. Lebedev[1], M. Krishnan[2], J. Skidmore[1], G.F. Swadling[1], A.J. Harvey-Thompson[1,5], M. Bocchi[1], M. Bennett[1], S.N. Bland[1], G. Burdiak[1], J.P. Chittenden[1], P. de Grouchy[1], G.N. Hall[1], E. Khoory[1], L. Pickworth[1], S. Stafford[1], L. Suttle[1], R.A. Smith[1], S. Patankar[1], K. Wilson-Elliot[2], R. Madden[2], A. Ciardi[3], and A. Frank[4]

[1]Imperial College London, London, UK
[2]Alameda Applied Sciences Corporation, Alameda, CA, USA
[3]Observatoire de Paris, Paris, France
[4]University of Rochester, Rochester, NY, USA
[5]Sandia National Laboratories, Albuquerque, NM, USA

Abstract

A supersonic (Mach 3-5), radiatively cooled plasma jet is produced by the ablation of plasma from a radial foil, a metallic disk subjected to a 1.4 MA, 250 ns current pulse from the MAGPIE generator. The ablated plasma converges on axis, producing a steady and collimated jet with a typical axial velocity of 100 km/s.

The study of jet-ambient interactions is achieved by introducing a neutral, cold gas above the foil using a fast valve with a supersonic gas nozzle. The system was adjusted to study different interaction geometries, and to vary critical parameters such as the jet-ambient density contrast. The effects of radiative cooling on the working surface of the jet are studied by varying the gas composition. Results from experiments and 3-D MHD simulations using the GORGON code will be presented and discussed.

Work supported by EPSRC Grant No. EP/G001324/1, by the NNSA under DOE Cooperative Agreements No. DE-F03-02NA00057 and No. DE-SC-0001063, by DOE SBIR Grant DE-FG02-08ER85030, and by a Marie Curie European Reintegration Grant.

Outflow collimation by a poloidal magnetic field

Andrea Ciardi[1], Tommaso Vinci[2], and Julien Fuchs[2]

[1]LERMA, Observatoire de Paris
[2]LULI, Ecole Polytechnique

Abstract

At both extremes of their lives, protostars and evolved stars eject powerful outflows which inject matter and energy into the surrounding interstellar medium, and play an important role in the stellar life cycle.

These outflows are essentially multi-components, consisting of stellar winds, disk winds, and jets which may coexist, and interact between them and with magnetized envelopes. An important class of models, which will be the focus of our talk, have addressed the general issue of outflow collimation by a large scale poloidal magnetic field.

We will present MHD simulations of a series of proposed laser experiments aimed at studying the expansion and interaction of a laser plume with a strong (40 T) magnetic field. The numerical results show the formation of elongated outflow cavities and the launching of highly collimated jets by shock re-focusing. We will discuss the possible implications of these promising results to astrophysical systems.

How to hide a supermassive black hole: AGN obscuration through dusty infrared dominated flows

Anton Dorodnitsyn[1,2], Tim Kallman[1], and G.S. Bisnovatyi-Kogan[3]

[1]NASA GSFC
[2]University of Maryland
[3]Space Research Institute, Moscow

Abstract

We explore a detailed model in which the active galactic nucleus (AGN) obscuration results from the extinction of AGN radiation in a global flow driven by the pressure of infrared radiation on dust grains. We assume that external illumination by UV and soft X-rays of the dusty gas located at approximately 1pc away from the supermassive black hole is followed by a conversion of such radiation into IR. Using radiation hydrodynamics simulations in a flux-limited diffusion approximation we find that the external illumination can support a geometrically thick obscuration via outflows driven by infrared radiation pressure in AGN with luminosities greater than 0.05 Ledd and Compton optical depth > 1.

Laboratory studies of magnetic reconnection

Hantao Ji[1]

[1]Princeton Plasma Physics Laboratory, Princeton University

Abstract

Magnetic reconnection, the efficient release of magnetic energy by topological rearrangement of field lines, is one of the most important and fundamental plasma processes in space, solar and more distant astrophysical plasmas. It plays key roles in a wide range of phenomena including solar flares, coronal mass ejections, solar wind propagation and dissipation, interaction of interplanetary plasma with Earth and other planetsâ magnetosphere, star formation, and explosive phenomena from strongly magnetized neutron stars. Despite the long history of magnetic reconnection research, the most important progress has been achieved only recently. Much of this progress was accomplished with valuable contributions from dedicated laboratory experiments, which have become increasingly well-controlled and well-diagnosed. This talk highlights a few examples such as quantitative tests of the classical Sweet-Parker model, two-fluid effects for fast reconnection, first detections of the electron diffusion region, and impulsive reconnection via local 3D flux rope dynamics. Looking into the future, a new theme of magnetic reconnection with multiple X-lines is emerging to possibly provide solutions for fast reconnection in large systems and for efficient particle acceleration as suggested by recent numerical and theoretical studies. Scientific opportunities for a next generation laboratory experiment to study magnetic reconnection in such regimes directly relevant to space and astrophysical plasmas will be described.

Astrophysical collisionless shocks

Anatoly Spitkovsky[1]

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Abstract

Collisions of supersonic flows occur frequently in astrophysics, and the resulting shock waves are responsible for the properties of many astrophysical objects, such as supernova remnants, Gamma Ray Bursts and jets from Active Galactic Nuclei. For typical astrophysical parameters the shocks are “collisionless" and form due to plasma instabilities and self-generated magnetic fields. These shocks are inferred to accelerate particles and in some cases strongly amplify magnetic fields. How this happens remains to be clarified through theory, observations and lab experiments. In this talk, I will present a summary of recent progress in modeling of particle acceleration in collisionless shocks using kinetic simulations with particle-in-cell (PIC) and hybrid methods. I will discuss a survey of properties of collisionless shocks as a function of shock speed and the magnetization of the medium. Both relativistic and nonrelativistic shocks transition from being mediated by magnetic reflection to filamentation instabilities as the magnetization of the medium decreases. The physics of the shock affects particle injection into the acceleration process. I will present simulations which show ab-initio Fermi acceleration of particles and address the injection efficiencies for electrons and ions. The fundamental physics of collisionless shocks is now addressable with laboratory experiments. I will discuss the physical constraints that need to be satisfied by such experiments, and the current progress of shock experiments on Omega.

Electron scale magnetic reconnection in a laser produced plasma

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Abstract

Electron scale magnetic reconnection in a laser-produced plasma is discussed. Under the influence of a weak-external magnetic field perpendicular to a plasma propagation axis, the plasma flow can be collimated due to the distortion of the magnetic field. The plasma collimation or the jet formation occurs even when the Larmor radius of the ions are much larger than the typical jet scales. The distorted magnetic field due to the plasma dynamic pressure is locally anti-parallel, i.e., magnetic reconnection is possible. We discuss the possibility of electron scale reconnection with experimental and numerical results.

Spatial and temporal evolution of extremely strongly laser driven magnetic reconnection

Jiayong Zhong[1], Yutong Li[2], Xiaogang Wang[3], Jiaqi Wang[3], Quanli Dong[2], Xun Liu[2], Xiaoxuan Lin[2], Dawei Yuan[2], Fei Du[2], Shoujun Wang[2], Chijie Xiao[3], Feilu Wang[1], Gang Zhao[1], and Jie Zhang[4]

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Abstract

Spontaneous electric (E) and magnetic (B) fields in moderate intensity laser plasmas are extremely high (10^6 G and $10^{(7-8)}$ V/m). The B fields were "frozen" and moved with high speed plasmas due to high magnetic Reynolds number. By using these fields to construct topology of non-equilibrium strongly driven magnetic reconnection is one big challenge. The experiment of extremely strongly-laser-driven magnetic reconnection is performed. The dynamic processes of reconnection are checked with different cases which show the optimized topology structure.

Collisionless shockwaves formed by counter-streaming laser-produced plasmas

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Abstract

Most astronomical and astrophysical shock waves are collisionless, which means that the shocks are not formed by coulomb collisions. This paper presents our experimental as well as theoretical investigations of collisionless shock waves with high-power laser facility, Shenguang II, in China. The collisionless shockwaves are observed during the interaction between two counter-streaming laser-produced plasmas. Numerical simulations indicate that the shockwaves are excited by electrostatic instability. The comparison of the dimensionless parameters of our experiment with those of SNRs indicates that it is feasible to scale our measurements to the astrophysical objects by transformation and similarity criteria.

Supernovae: the gift that keeps on giving

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Abstract

I will briefly review the evidence from thermonuclear supernovae for cosmic acceleration and the nature of dark energy. The most promising path to more accurate and certain knowledge is to observe SN Ia in the near infrared.

Then I will sketch new evidence on the nature and the effect of core collapse supernovae, using Hubble Space Telescope observations of SN 1987A to illustrate the forms of evidence that are contained in the expanding debris and the interaction with circumstellar gas.

Designs and implementation plan for highly nonlinear ablative Rayleigh-Taylor Instability experiments on the National Ignition Facility

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B. Remington[2], S. Liberatore[1], H.S Park[2], L.Jacquet[1], F. Girard[1],
D. Bradley[2], O.Poujade[1], S. Sarkar[5], D. Galmiche[1], J-P. Jadaud[1],
P. Loiseau[1], and L. Videau[1]

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Abstract

In the context of NIF Basic Science program we propose to study on the National Ignition Facility ablative Rayleigh-Taylor Instability (RTI) in transition from weakly nonlinear to highly nonlinear regimes. Based on the analogy between flame front and ablation front [1], highly nonlinear RTI measurements at the ablation front can provide important insights into the initial deflagration stage of thermonuclear SNe Ia. NIF provides a unique platform to study the rich physics of nonlinear and turbulent mixing flows in High Energy Density plasmas because it can accelerate targets over much larger distances and longer time periods than previously achieved on the NOVA [2] and OMEGA [3,4] lasers. In one shot, growth of RT modulations can be measured from the weakly nonlinear stage near nonlinear saturation levels to the highly nonlinear bubble-competition, bubble-merger regimes and perhaps into a turbulent-like regime. The role of ablation on highly-nonlinear RTI evolution will be comprehensively studied by varying ablation velocity using indirect and direct-drive platforms. We will present detailed hydrocodes designs of these platforms [5] and discuss the implementation plan for these experiments which use NIF diagnostics already qualified.

[1] P. Clavin and L. Masse, Phys. Plasmas 11, 690 (2004).
[2] B. Remington et al., Phys. Plasmas 2, 1, (1995).
[3] L. Masse, A. Casner et al., Phys. Rev. E 83, 055401 (2011).
[4] V. Smalyuk et al., Phys. Plasmas 13, 056312 (2006).
[5] A. Casner, V. Smalyuk et al., submitted to Phys. Plasmas.

Laboratory basic science, hydrodynamic growth experiments on OMEGA

V. A. Smalyuk[1]

[1]LLNL

Abstract

Recent hydrodynamic growth experiments, a part of the Laboratory Basic Science (LBS) program on OMEGA, will be reviewed. These experiments consisted of modulation growth measurements due to Richtmyer-Meshkov (RM), Rayleigh-Taylor (RT), and Kelvin-Helmholtz (KH) instabilities. In RM experiments, planar foils with thicknesses ranging from 15 to 100 μm were driven with laser beams at intensity $5 \times 10^{13}\ W/cm^2$. For each foil thickness, the modulations seeded by laser imprinting and amplified due to RM instability were measured near the shock breakout time, which is longer in thicker foils. This allows using optimum backlighter x-ray energy for each foil, resulting in most sensitive modulation measurements. Evolution of 2D sinusoidal and 3D broadband modulations in RM phase will be presented. Modulations developed by RM instability were used as initial seeds for RT growth experiments. These experiments studied dependence of the RT instability as a function of initial conditions. Planar foils with thicknesses ranging from 15 to 100 μm were accelerated to the same distance travelled, such that the RT growth factors are the same for all targets. Dependence of the final modulation levels amplified by RT instability from initial conditions at the beginning of acceleration will be presented. Shear-flow, KelvinâHelmholtz (KH) turbulent mixing experiments were performed using laser-driven shock waves propagated through a low-density plastic foam placed on top of a higher-density plastic foil. Behind the shock front, lower-density foam plasma flowed over the higher-density plastic plasma, such that the interface between the foam and plastic was KH unstable. The initial perturbations consisted of pre-imposed, sinusoidal 2D perturbations, and broadband 3D perturbations due to surface roughness at the interface between the plastic and foam. The measured evolution of the mixing layer width will be compared with mixing models and 2D simulations.

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Unlocking the secrets of supernovae through their spectra

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[2]Laboratoire d'Astrophysique de Marseille, Université de Provence, France

Abstract

Modern survey telescopes will discover thousands of supernovae (SNe). The discoveries will identify new SN classes, refine the statistics of SN occurrence as a function of class and host galaxy properties, allow the direct identification of SN progenitors, and identify SNe for which spectra can be obtained throughout the SN's temporal evolution. In this presentation we present and discuss results coming from a series of investigations on Type Ia, Ib, Ic, and Type II SNe. Using CMFGEN, we solve the non-LTE time-dependent radiative transfer equation at $\sim 10^5$ frequencies, from the far UV to the far-IR, yielding simultaneously the spectral evolution as well as the multi-band light curves from approximately 1 day after the explosion through the photospheric phase, and into the nebular phase. The calculations are fully non-LTE, allow for a multitude of atomic processes (bound-bound, bound-free, free-free, collisional, charge exchange, and Penning ionization) and include non-thermal excitation and ionization from non-thermal electrons created by the degradation in energy of high energy (~MeV) gamma-rays. The proper treatment of all these processes requires a vast amount of atomic data. Not all the atomic data is available, and the quality of the available atomic data varies considerably. We have confirmed the results of Utrobin and Chugai (2005) that time dependent terms must be included in the statistical equilibrium equations in order to model the Hα evolution of SN 1987A, shown that time dependent terms influence other spectral features, and demonstrated that these conclusions also apply to the modeling of Type II SNe in general. The inclusion of non-thermal processes has allowed us to model Hα and He I line emission in Type II SNe into the nebular phase, and to model the He I line emission in Type IIb/Ib SNe. Our calculations show that the apparent He deficiency in Ic SNe is unlikely to be real – instead the absence of He I lines in SN Ic spectra is more likely related to inefficient excitation of He I ions. Simply by varying the amount of mixing we are able to create SNe of Type Ib and Ic using the SAME progenitor model. We have also successfully applied CMFGEN to model Type Ia SNe, and are currently exploring the complex line formation and line-blanketing effects in these ejecta composed primarily of metals and intermediate-mass elements.

The physics of reaction rates in stellar environments

Michael Wiescher[1]

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Abstract

The nuclear energy generation and the origin of the elements in stars is controlled by the reaction rates of nuclear processes. Thermonuclear reaction rates drive stellar evolution and stellar explosions, pycnonuclear reaction rates control the energy production in high density environments as found in White Dwarfs or the crust of Neutron stars. The nuclear reaction rates depend sensitively on the nuclear reaction cross sections and are typically defined by low energy threshold phenomena. These phenomena are extremely difficult to measure and therefore depend largely on theoretical interpretations; this introduces large model dependent uncertainties into the reaction rate. I will demonstrate these phenomena on the example of a number of carbon driven nuclear fusion processes, 12C(α, γ)16O, 12C+12C, which define the ignition conditions of type Ia supernovae and fusion between very neutron rich carbon isotopes which have been predicted as internal heat source in the deeper layers of the neutron star crust.

Strange matter in neutron stars and core-collapse supernovae

I. Sagert[1], T. Fischer[2], M. Hempel[3], G. Pagliara[4], J. Schaffner-Bielich[5], F.-K. Thielemann[3], and M. Liebendoerfer[3]

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Abstract

Born in core-collapse supernovae, neutron stars contain matter at densities far beyond nuclear saturation. Though recent neutron star mass measurements provide information about the properties of high density nuclear matter, the interior composition of neutron stars is till today not known and possible scenarios range from pure nucleonic matter, to the presence of hyperons, or even quark matter.

I will discuss signals from the possible appearance of hyperons and strange quark matter during the birth of neutron stars in supernova explosions. Special emphasis will be placed on the early post-bounce appearance of strange quark matter in the proto neutron star interior. It has been shown that in such a case the proto neutron star can collapse to a more compact quark-hadron hybrid star configuration. The collapse can trigger the formation of a shock wave which leads to a successful supernova explosion and leaves an imprint on the neutrino signal. I will discuss these dynamical features, also with respect to their compatibility with the recent measurement of the two solar mass pulsar PSR J1614-2230.

Corresponding publications, see e.g.:

"Signals of the QCD phase transition in core-collapse supernovae" I. Sagert, M. Hempel, G. Pagliara, J. Schaffner-Bielich, T. Fischer, A. Mezzacappa, F.-K. Thielemann,M. Liebendoerfer, Phys. Rev. Lett. 102, 081101 (2009)

"Core-collapse supernova explosions triggered by a quark-hadron phase transition during the early postbounce phase" T. Fischer, I. Sagert, G. Pagliara, M. Hempel, J. Schaffner-Bielich, T. Rauscher, F.-K. Thielemann, R. Kaeppeli, G. Martinez-Pinedo, M. Liebendoerfer The Astrophysical Journal Supplement, Volume 194, Issue 2, article id. 39 (2011)

"Strange matter in core-collapse supernova" I. Sagert, T. Fischer, M. Hempel, G. Pagliara, J. Schaffner-Bielich, F.-K. Thielemann, M. Liebendoerfer arXiv:1112.6328

ZAPP: The Z Astrophysical Plasma Properties collaboration

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Abstract

The new generation of z-pinch, laser, and XFEL facilities opens the possibility to produce astrophysically-relevant laboratory plasmas with energy densities beyond what was previously possible. Furthermore, macroscopic plasmas with uniform conditions can now be created, enabling more accurate determination of the material properties. This presentation will provide an overview of our research at the Z facility investigating stellar interior opacities, AGN warm-absorber photoionized plasmas, spectral line emission from photoionized plasmas near accretion powered objects, and white dwarf photospheres. The Z Astrophysical Plasma Properties collaboration is staging Z experiments that simultaneously investigate all four of these topics. Stellar opacities are an essential ingredient of stellar models and opacity models have become highly sophisticated, but laboratory tests have not been done at the conditions existing inside stars. Our research is presently focused on measuring Fe at conditions relevant to the base of the solar convection zone, where the electron temperature and density are believed to be 190 eV and 9×10^{22} e/cc, respectively. The second project is aimed at testing atomic kinetics models for photoionized plasmas. Photoionization is an important process in many astrophysical

plasmas and the spectral signatures are routinely used to infer astrophysical objectâs characteristics. However, the spectral synthesis models at the heart of these interpretations have been the subject of very limited experimental tests. Our current research examines photoionization of neon plasma subjected to radiation flux similar to the warm absorber that surrounds active galactic nuclei. The third project is studying photoionized silicon plasmas, with the goal of determining the importance of Resonant Auger Destruction on spectra that emerge from photoionized plasmas near x-ray binaries. The fourth project is aimed at producing a white dwarf photosphere in the laboratory. Emergent spectra from the photosphere are used to infer the star‘s effective temperature and surface gravity. The results depend on knowledge of H, He, and C spectral line profiles under conditions where complex physics such as quasi-molecule formation may be important. These profiles have been studied in past experiments, but puzzles emerging from recent white dwarf analysis have raised questions about the accuracy of the line profile models. Proof-of-principle data has been acquired that indicates radiation-heated quiescent plasmas can be produced with ~ 1 eV temperature and 10^{17} â 10^{19} e/cc densities, in a $\sim 20\text{cm}^3$ volume. Such plasmas would provide a valuable platform for investigating numerous line profile questions.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

An experimental platform for creating white dwarf photospheres in the laboratory

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[2]Sandia National Laboratories

Abstract

We present hydrogen Balmer line profiles in emission, absorption, and transmission at plasma conditions observed in white dwarf (WD) photospheres ($n_{\mathrm{e}} \sim 10^{17}$ cm^{-3}, $T_{\mathrm{e}} \sim 1$ eV); these profiles will be used to constrain and eventually benchmark the latest theoretical WD atmosphere models (e.g., Tremblay Bergeron 2009), which, used with the spectroscopic method (e.g., Bergeron et al. 1992), are responsible for determining fundamental parameters (i.e., effective temperature, mass) for tens of thousands of WDs. Our experiments, performed at the Z Pulsed Power Facility at Sandia National Laboratories, intercept the bath of X-rays generated from a z-pinch dynamic hohlraum and use them to drive plasma formation in a gas cell. The experimental platform is unique compared to past experiments in that the heating of the plasma is radiation-dominated, providing the opportunity to explore time-dependent, non-LTE, collisional-radiative atomic kinetics. It is also the first time hydrogen Balmer lines have been measured in absorption/transmission at these conditions in the laboratory.

Observations of anomalous plasmoid ejection, plasma jets and electron diffusion regions of magnetic reconnections in laser-plasma experiments

Quan-Li Dong[1], Shou-Jun Wang[1], Da-Wei Yuan[1], Xun Liu[1], Yu-Tong Li[1], Xiao-Xuan Lin[1], Hui-Gang Wei[1], Jia-Yong Zhong[1], Jian-Rong Shi[1], Bo-Bin Jiang[1], Kai Du[1], Yong-Jian Tang[3], Neng Hua[3], Zhan-Feng Qiao[3], Kui-Xi Huang[3], Ming Chen[3], Jian-Qiang Zhu[4], Gang Zhao[2], Zheng-Ming Sheng[1,5], and and Jie Zhang[1,5]

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Abstract

The driving mechanism of the solar flares and coronal mass ejections is a topic of ongoing debates except the consensus that the magnetic reconnection plays key roles during the impulsive process. While present solar researches mostly depend on observations and theoretical models, laboratory experiments based on high energy density facilities provide the third method for quantitatively comparing astrophysical observations and models with data achieved in experimental settings. In this article, we show laboratory modelling of the solar flares and coronal mass ejections by constructing the magnetic reconnection system with two mutually approaching laser-produced plasmas circumfused of self-generated megagauss magnetic fields. Due to Euler similarity between laboratory and solar plasma systems, present experiments demonstrate the morphological reproduction of flares and coronal mass ejections in solar observations in a scaled sense, and confirm the theory and model predictions about the current-sheet-born anomalous plasmoid as the initial stage of coronal mass ejections, and the behavior of moving-away plasmoid stretching the primary reconnected field lines into a secondary current sheet conjoined with two bright ridges identified as the solar flares. On the other hand,

the experimental results also present three elongated electron diffusion regions, which are similar to tens of magnetotail observations through last decades.

Challenges of modeling astrophysical MHD

James M. Stone[1]

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Abstract

Most of the visible matter in the Universe is a plasma, that is a dilute gas of electrons, ions, and neutral particles. Studying multidimensional, time-dependent and/or highly nonlinear processes in astrophysical plasmas usually requires numerical methods. While numerical algorithms for compressible MHD are now widely available, the challenge for the future is to extend these methods with additional physics important in astrophysical systems. This includes non-ideal MHD effects in weakly ionized plasmas, the addition of anisotropic transport coefficients in weakly collisional plasmas, and perhaps most challenging, the addition of radiation transport to include both energy and momentum transport by photons. I will describe some problems in astrophysics which motivate the development of such methods, describe recent advance in numerical algorithms for MHD and their implementation on parallel processors, and briefly describe some of what we have learned from application of the methods.

Full-scale modeling of Weibel mediated collisionless shocks in laboratory scenarios

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Abstract

Weibel mediated collisionless shocks are believed to occur in many astrophysical scenarios, but the conditions for the generation of these shocks in laboratory are not yet fully understood.

Using ab initio multi-dimensional relativistic PIC simulations, we show that Weibel mediated collisionless shocks can be driven in laboratory by the interaction of current/near-future high power laser pulses with overcritical plasmas. The laser acts like a piston, pushing the plasma and generating a flow of relativistic electrons that propagate through the target. The relativistic incoming flow and the cold counterstreaming flow (associated with the return current) go Weibel unstable leading to a strong compression and to the formation of a shock. The Weibel-driven magnetic fields reach 10

We demonstrate the possibility of controlling the shock properties by tuning the laser intensity, the laser polarization, and the target density, opening the way for the first in situ study of Weibel mediated shocks.

Collaborative comparison of high-energy-density physics codes

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[2]University of Chicago
[3]Los Alamos National Laboratory

Abstract

Performing radiation-hydrodynamic simulations is vital to the understanding of laboratory astrophysics experiments. A number of codes have been developed for this purpose. A collaboration has begun to compare several of these codes, including CRASH (Unversity of Michigan), FLASH (University of Chicago), RAGE and CASSIO (LANL) and HYDRA (LLNL). We are in the process of testing these codes on a wide variety of problems, ranging from very simple tests to full laboratory astrophysics experiments. The algorithms and physics models differ significantly between these codes, so complete agreement is not expected, especially on the full-experiment simulations. The goal is to understand the differences between the codes and how these differences influence the results. We intend to determine which codes contain the most accurate algorithms and physics models and, where possible, to improve the other codes to produce more faithful representations of the experiments. The first set of tests are simple temperature relaxation problems in an infinite, uniform medium. The second suite of tests was designed to test the diffusion solvers (both conduction and radiation) in the codes. Following this, tests will be performed that include hydrodynamic effects. Results of these comparisons will be presented. The eventual goal is to compare the results from all of the codes on simulations of radiative shock experiments being performed by The Center for Radiative Shock Hydrodynamics at the University of Michigan and to understand any discrepancies between the results of the simulations and the experiments.

Computer experiments for supersonic turbulent flows in high-energy density plasmas

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Abstract

We investigate turbulent structure emerging in shocked high-energy density plasmas produced in laser experiments by means of computer simulations, with and without a pre-existing magnetic field. Such situations commonly occur in astrophysical environments. One particularly interesting astrophysically-relevant problem is the role turbulence plays in the generation and amplification of magnetic fields.

Our early analysis of laser-driven turbulent flows indicated that one can obtain plasmas characterized by Reynolds number on the order of Re$\sim$1000 on the Omega laser. Using scaling laws one may expect that in a similar experiment executed at the National Ignition Facility one could produce flows with Re$\sim$5000. This regime is close to where the transition to turbulence is expected to occur. One of our goals is to optimize experimental conditions to achieve Re$\sim$10,000, enabling the study of transition to turbulence in HED plasmas. The scaling for magnetized HED flows shows that designing an experiment characterized by a high ($\approx 1 \times 10^4$) Re number and a least a moderate (≈ 1) magnetic Prandtl number is quite challenging. To this end, we investigate the sensitivity of the model experimental outcomes to experimental conditions such as the laser drive, material properties (plasma Z), and variations in target fabrication and target alignment. We also briefly discuss the suitability of such an experiment for model validation studies.

A relativistic magnetohydrodynamic code based on upwind scheme

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Abstract

Building a relativistic magnetohydrodynamic (RMHD) code based on upwind scheme is a challenging project, because analytic expressions for eigenvalues and eigenvectors were not yet given. In this work, we first have obtained an analytic form for eigenvalues, which is complicated but manageable. We then have found that eigenvectors, when expressed in terms of eigenvalues, can be written down in a very simple form. Here, we present a code based on the total variation diminishing (TVD) scheme using the eigenvalues and eigenvectors, and show tests performed with the code.

Experiments to probe warm dense matter conditions for planetary science

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Abstract

In the last decade hundreds of extra-solar planets have been discovered. Our understanding of the formation, evolution and internal structure of these objects depends critically on accurate models of material properties at extreme pressures (< 10 TPa) and but modest temperatures ($<$ 10000 K). These states are in the regime of so-called âwarm dense matterâ. Experiments to benchmark models of material properties in this regime are an important ingredient of this area of study. In parallel with the discoveries of exoplanets new experimental capabilities have emerged that enable the creation and probing of warm dense matter states. This review will survey the basic techniques used to create and probe warm dense matter states in the laboratory, and describe the progress in the development of these experimental capabilities. The review will include a selection of highlights from recent research.

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Phase separation in giant planet interiors and novel first-principles simulation of plasmas

B. Militzer[1]

[1]University of California, Berkeley

Abstract

The Kepler satellite has detected over 2000 planets in distant solar systems. Starting with a brief overview over the search for such extrasolar planets, this talk will discuss the state of matter at high temperature and pressure conditions that prevail in the interiors of giant planets. We describe how data from the Galileo mission to Jupiter has been combined with first-principles simulations to demonstrate that hydrogen and helium phase-separate at high pressure causing helium rain to occur in the interior of this planet [1]. We then characterize the state of matter in the cores of giant planets. In particular, we focus on the question whether typical core materials like metals, rock, and ices are stable when they are exposed to metallic hydrogen at megabar pressures and temperatures exceeding 10,000 K. By combining Gibbs free energy calculations with density functional molecular dynamics simulations, we could show that water ice [2] and magnesium oxide [3] dissolve into the layers of metallic hydrogen that surround Jupiterâs core. This implies that the cores of Jupiter, Saturn, and many exoplanets have, at least partially, been eroded.

Furthermore, we report simulation results from an all-electron path integral Monte Carlo (PIMC) method that we developed for the regime of warm dense matter and applied to study hot, dense water and carbon plasmas [4]. We extend PIMC simulations beyond hydrogen and helium to elements with core electrons. PIMC pressures, internal energies, and pair-correlation functions compare well with density functional molecular dynamics at lower temperatures and enable the construction of a consistent equation of state over the pressure-temperature range of $1-50$ Mbar and $10^4 - 10^9$ K.

[1] H. F. Wilson and B. Militzer, "Sequestration of noble gases in giant planet interiors", Phys. Rev. Lett. 104 (2010) 121101

[2] H. F. Wilson, B. Militzer, " Rocky core solubility in Jupiter and giant exoplanets", Phys. Rev. Lett., in press (2012).

[3] H. F. Wilson, B. Militzer, "Solubility of water ice in metallic hydrogen: consequences for core erosion in gas giant planets", Astrophys. J. Lett. 745 (2012) 54.

[4] K. P. Driver, B. Militzer, "All-Electron Path Integral Monte Carlo Simulations of Warm Dense Matter: Application to Water and Carbon Plasmas", Phys. Rev. Lett., in press (2012).

Thermodynamical and transport properties of dense H-He mixtures

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Abstract

Hydrogen and helium are the main components of giant planets like Jupiter or Saturn. Although the properties of pure hydrogen and helium are reasonably well understood nowadays, the behavior of the mixture at high pressure remains poorly known. However, this is of fundamental importance to understand the structure and the evolution of these giant planets. For instance, the scenarios of cooling for Saturn are not compatible with its age, unless a demixing process of H-He occurs in the interior. But the existence of such a phase separation still needs to be confirmed by numerical simulations and/or laser-driven experiments.

We will present quantum molecular dynamics (QMD) simulation results of equimolar mixtures of hydrogen and helium, exploring densities from 0.24 to 3.5 g/cm^3 and temperatures from 1000 K to 17400 K ($\sim$ 0.1 to 1.5 eV). This is a range of parameters for which the mixture is a partially pressure-ionized plasma.

First, we will present thermodynamical properties as well as structural analysis which characterize the behavior of the plasma. Secondly, we will present results on the transport properties (electrical and thermal conductivities and reflectivity) of the H-He mixture: these quantities are important observables for the laser-driven experiments dealing with hydrogen-helium mixtures. Finally, we will discuss the relevance of all these diagnostics for the detection of a phase separation in H-He mixtures experimentally as well as in simulations.

Improvements in equation of state and opacities for warm dense matter

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Abstract

We present a study of laser produced radiative shocks in a Xenon gas made with the 2D simulation code ARWEN. The time evolution of the plasma is computed using a conservative multimaterial hydrodynamic method while we use a multigroup radiation transport package to get the plasma radiative properties.

We have improved the calculation of equation of state and opacity tables suitable for including in simulation codes to study laboratory astrophysics as well as other processes like ICF and FI or X-ray secondary sources. We have improved the original QEOS model to fit the available experimental data and molecular dynamics simulations. For opacity calcu- lations we use the code BiGBART in LTE conditions, with self-consistent data generated with the Flexible Atomic Code. Non-LTE effects are ap- proximately taken into account by means of the improved RADIOM model, which makes use of existing LTE data tables.

Numerical simulations of electron heating during energy transfer in a laser driven collisionless shock

S. Davis[1], R. Capdessus[1], E. d'Humières[1], S. Jequier[1], V. Tikhonchuk[1], A.V. Brantov[2], and S. Bochkarev[2]

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Abstract

We present results of two dimensional simulations of the Weibel instability arising from collisionless shock formation simlar in scale to those seen in astrophysics. In this paper, using 2D particle-in-cell simulations, we present the interaction of a sub-relativistic, laser-generated neutralized proton beam with a preformed plasma of the same density. Our major interest is to study the energy transfer from the ion stream to the electrons, electric and magnetic fields under the conditions where the particle collisions do not play any role. The origin of the strong electron heating and ion slowing down is the Weibel-like beam filamentation driven by the ion drift. The process of collisionless shock formation is explained by a stochastic electron heating followed by generation of quasistatic electric field. This yields insight on the processes occurring in the interstellar medium (ISM) and gamma-ray burst afterglows.

Laboratory photoionized plasma experiments relevant for astrophysics

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Abstract

Many astrophysical environments such as x-ray binaries, active galactic nuclei, and accretion disks of compact objects have photoionized plasmas. These low-density plasmas are driven by an intense, broad-band x-ray flux and, unlike collisionally-driven plasmas, their atomic kinetics is dominated by photoionization and photoexcitation. Detailed x-ray spectral observations performed with the Chandra and XMM-Newton orbiting telescopes provide critical information on the state of the photoionized; however, the complexity of the astrophysical environment makes the spectral analysis challenging. Developments in pulsed-power and high-power laser drivers for performing high-energy density laboratory plasma experiments have led to the availability of powerful x-ray sources that enable the study in the laboratory of photoionized plasmas relevant for astrophysics under well characterized plasma and driver conditions. This is important since astrophysical models to interpret data from photoionized plasmas have been developed from theory and thus laboratory benchmarks provide an important opportunity to test modeling codes. We review present and future opportunities to perform laboratory photoionized plasma experiments and their relevance and connection to astrophysics. We also discuss the requirements of these experiments including hydrodynamic, atomic physics, time-scales and x-ray drive considerations as well as the instrumentation and measurements that can be performed.

This work is sponsored in part by the National Nuclear Security Administration under the High Energy Density Laboratory Plasmas grant program through DOE Grant DE-FG52-09NA29551.

Alternative methods of producing photoionised plasmas in the laboratory

E.G. Hill[1] and S.J. Rose[1]

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Abstract

In this talk I will discuss new methods for overcoming the high densities and low radiation temperatures obtained in the laboratory relative to astrophysical photoionised systems[1].

The kinetics of the Helium-like ions in astrophysical and laboratory plasmas will be discussed and parametrized, and a method of producing radiation fields which cause atomic kinetics characteristic of a high colour temperature radiation field will be presented, accompanied by simulations both of experiments based on these ideas and of previously performed photoionised plasma experiments.

[1] Hill E.G. and Rose S.J. HEDP 7 (2011)

The evolution of a radiative shock system on the Omega Laser

C.C. Kuranz[1], R.P. Drake[1], M.J. Grosskopf[1], C.M. Krauland[1], C.M. Huntington[1], B. Torralva[1], E. Rutter[1], S.R. Klein[1], and D.C. Marion[1]

[1]University of Michigan

Abstract

Radiative shocks, which are in a regime where most of the incoming energy flux is converted into radiation, are commonly found in astrophysical systems including accretion phenomena, supernova and stellar shocks. This type of shock can be created in a laboratory using a high-powered laser. We have performed experiments on the Omega laser facility that irradiate a 20 μm thick Be disk with about 4 kJ of laser energy in a 1 ns pulse. This shocks and accelerates the disk into a Xe or Ar gas at 1.1 atm. These radiative shocks can reach velocities of over 100 km/s. A 3D, MHD code with a radiation solver is being developed at the Center for Radiative Shock Hydrodynamics (CRASH) that will model this experiment. Diagnostics for this experiment have included streaked and imaging x-ray radiography, optical pyrometry, and VISAR. Experimental results include observations ranging from shock breakout of the Be disk at about 0.5 ns until 26 ns after the laser pulse is initiated. These results will be presented.

This work is funded by the Predictive Sciences Academic Alliances Program in NNSA-ASC via grant DEFC52- 08NA28616, by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-FG52-09NA29548, and by the National Laser User Facility Program, grant number DE-NA0000850.

Expanding shock waves from 100 Gbar implosions on the National Ignition Facility

Siegfried Glenzer[1], Andrea Kritcher[1], Art Pak[1], Tammy Ma[1], Steven Ross[1], Steve Glenn[1], David Bradley[1], Tilo Döppner[1], Joseph Ralph[1], Riccardo Tommasini[1], Andrew MacPhee[1], Nobuhiko Izumi[1], Eduard Dewald[1], John Moody[1], Sebastian LePape[1], Andrew Mackinnon[1], Steven Weber[1], Pierre Michel[1], Laurent Divol[1], David Farley[1], John Klein[2], and George Kyrala[2]

[1]Lawrence Livermore National Laboratory
[2]Los Alamos National Laboratory

Abstract

Inertial confinement fusion implosion experiments on the National Ignition Facility show a supernova-like emission ring after peak capsule compression. These experiments use thermonuclear fuel fielded as a cryogenic layer on the inside of a spherical plastic capsule in the center of a cylindrical gold hohlraum. Heating the hohlraum with 192 laser beams with a total laser energy of 1.6 mega joules compresses the initially 2.2-mm diameter capsule by a factor of 30 to a spherical dense fuel shell that surrounds a central 3 keV hot-spot plasma of 50 μm diameter. X-ray and neutron imaging of the compressed core and fuel indicate high fuel areal densities of 1 g cm^{-2} with fuel densities approaching 600 g cm^{-3}. This achievement is the result of the first hohlraum and capsule tuning experiments where the stagnation pressures that have been systematically increased by more than a factor of 10 by fielding low-entropy implosions through the control of radiation symmetry, small hot electron production, and proper shock timing. The implosions reach stagnation pressures above 100 Gbar driving a spherical shock that is expanding into the ambient plasma with velocities of 300 km/s. The comparison with radiation-hydrodynamic simulations indicates that the shocks provide a signature of the implosion energy.

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Asymptotic accuracy of the equilibrium-diffusion approximation

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Abstract

The equilibrium-diffusion approximation takes two forms: one that relates to a static medium and one that relates to the non-relativistic radiation-hydrodynamics equations. Both of these forms have been previously derived via a formal asymptotic expansion procedure. For the case of a static medium, Morel has shown that the approximation is correct to first order rather than simply leading (zeroth) order, and used this result to investigate the asymptotic accuracy of several flux-limited diffusion theories. For the case of the radiation-hydrodynamics equations, Lowrie, Morel, and Hittinger demonstrated accuracy only to leading order. We extend their radiation-hydrodynamic analysis to show that the equilibrium-diffusion approximation is correct to first order. In addition, we use our results to investigate the accuracy of a grey P-1 approximation made in the comoving frame versus the accuracy of a grey P-1 approximation made in the lab frame. We stress that these are two fundamentally different approximations, i.e., one cannot be obtained from the other via a Lorentz transformation. Since in the equilibrium-diffusion limit the radiation intensity only becomes isotropic in the comoving frame, but not the lab frame, one might expect the lab-frame P-1 approximation to be flawed in this limit. However, our analysis shows that both approximations are correct to first order in this limit, which represents the highest order of accuracy that can be expected.

Interstellar dust - a review

Farid Salama[1]

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Abstract

The study of the formation and the destruction processes of cosmic dust is essential to understand and to quantify the budget of extraterrestrial organic materials. Although dust with all its components plays an important role in the evolution of interstellar physics and chemistry and in the formation of organic materials, little is known on the formation and destruction processes of carbonaceous dust.

Laboratory experiments that are performed under conditions that simulate interstellar and circumstellar environments to provide information on the nature, the size and the structure of interstellar dust particles, the growth and the destruction processes of interstellar dust and the resulting budget of extraterrestrial organic molecules.

A review of the properties of dust and of the laboratory experiments that are conducted to study the formation processes of dust grains from molecular precursors will be given.

Basic scalings for collisionless shock experiments

D.D. Ryutov[1], N.L. Kugland[1], H.-S. Park[1], C. Plechaty[1], B.A. Remington[1], and J.S. Ross[1]

[1]Lawrence Livermore National Laboratory

Abstract

Issues that one has to face when designing and performing the collisionless shock experiments include the scalability from a plasma with predominantly hydrogen ions (as is the case in most of astrophysical systems) to the plasmas of heavier elements, like beryllium or carbon, which are more readily usable in the laboratory. Sometimes, one has to work with a plasma of mixed composition, e.g. CH2 plasma. The change of the ion species leads to a change of the characteristic scales and growth rates of collisionless instabilities and eventually affects measurable parameters like the width of the shock transition. In this paper, a set of general scaling constraints is provided that allows for a scaled substitution of one element by the other. Reduced versions suitable for electrostatically-mediated and magnetically-mediated models of the shocks are described. The presence of these scaling relations can serve as a basis for making comparisons between models and selecting the most plausible models. One more phenomenon that may affect the shock properties are intra-jet collisions, whose frequency may be non-negligible even if the collisions between the particles of two jets are very rare. We discuss the role of this phenomenon in the shock formation.

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Magnetized jet experiments and radiative shocks driven by pulsed power

S.V. Lebedev[1]

[1]Imperial College

Abstract

Results of recent experimental studies of supersonic, radiatively cooled plasma jets, performed at the pulsed power MAGPIE facility (1.5MA, 250ns) at Imperial College will be presented. The experiments are scalable to astrophysical flows in that critical dimensionless numbers such as the plasma collisionality, the plasma beta, Reynolds number and the magnetic Reynolds number are all in the astrophysically appropriate ranges. The presentation will include discussion of the dynamics of magnetically driven jets, in particular formation of episodic outflows. Studies of the interaction of jets with ambient medium (He, Ar, Kr gases), showing the effects of radiative cooling on the morphology of the interaction, will be also presented. Results of first experiments aimed on formation of rotating plasma discs generated by cylindrically converging plasma streams in wire array z-pinch with added cusp magnetic fields will be discussed. Quantitative information on the plasma parameters in all these experiments is provided by several spatially and temporally resolved diagnostics, including direct measurements of flow velocities using Doppler shift of Thomson scattering spectra.

[1] A. Ciardi, S.V. Lebedev, A. Frank et al., The Astrophysical Journal, 691: L147âL150 (2009)

[2] F.A. Suzuki-Vidal, M. Bocchi, S.V. Lebedev et al., Physics of Plasmas, 19, 022708 (2012).

Collisionless interaction between axial plasma jet and ambient, magnetized plasma measured using laser-induced fluorescence

Jeffrey Bonde[1], Stephen Vincena[1], and Walter Gekelman[1]

[1]University of California, Los Angeles

Abstract

The field-aligned supersonic expansion of a laser-produced carbon plasma through an ambient, magnetized argon plasma ($n \sim 2{\times}10^{12} cm^{-3}$, $v_{exp}/v_A \sim 1$, $v_{exp}/c_s \sim 30$) is studied in the 20m Large Plasma Device at UCLA. A laser-induced fluorescence diagnostic characterized the interactions of the background plasma species as the carbon plasma expanded. Using the Ar-II ions' 611.5 nm transition line, a planar beam formed by a YAG-pumped, tunable dye laser sampled the Doppler broadened distribution function of the background plasma. A fast shutter ($\geq$3 ns) CCD camera provided 2-D spatial and temporally resolved images of the fluorescence. The distribution function from the transition spectra showed a significant fraction of these excited argon ions accelerated to an ion sound speed Mach number of 2-3. Additionally, a spatially localized bundle of higher pressure argon ions is found to form near the front of the carbon plasma jet with a velocity approximately equal to the argon Alfven speed. Magnetic probes followed the evolution of the background field and the generation of Alfven radiation. Langmuir probe measurements supplemented the diagnostics with time of flight measurements and spectral analysis of the wake.

This experiment is conducted at the Basic Plasma Science Facility and funded by the DOE and NSF.

The formation of magnetized molecular clouds: new results and experimental possibilities.

Adam Frank[1]

[1]University of Rochester

Abstract

Molecular Clouds are the birthplace of stars yet fundamental questions as to their origin remain unresolved. Do clouds form from colliding flows, or do they condense out of the background ISM? Are their observed velocity line-widths due to a turbulent cascade of initial and/or externally driven kinetic energy, or is it the result of gravitational collapse? Here we compare the results of various simulations of cloud formation with observed cloud properties to constrain mechanisms related to formation and turbulence.

Using 3-D AMR multi-physics calculations via the code AstroBEAR we carry forward a series of simulations which allow us to compare and contrast two mechanisms for the generation of turbulence: colliding large scale flows which both form the clouds and seed their turbulent motions and internal driving of turbulent motions via interacting stellar outflows.

As the study of cloud formation and turbulence is of great interest to the astrophysical community we also introduce possible HED laboratory experiments. In particular we focus on colliding magnetized flows and interacting jets as mechanisms for exploring turbulence in experiments.

Magnetized turbulence in astrophysical fluids

Jungyeon Cho[1]

[1]Chungnam National University, Korea

Abstract

Magnetized turbulence is omnipresent in astrophysical fluids. I will briefly introduce properties of magnetized turbulence. Astronomy deals with various length scales. In general, different descriptions should be used for different scales. On large scales, astrophysical turbulence can be described in the framework of magnetohydrodynamics (MHD). In this talk, I will consider two extreme regimes of MHD turbulence. First, I will consider MHD turbulence in the presence of a strong mean field. I will discuss energy cascade and structure of turbulence in this regime. Second, I will consider MHD turbulence in the presence of a weak/no mean field. In this regime, growth of magnetic fields is of great importance. I will show that magnetic fields can grow fast by turbulent motions and discuss its astrophysical implications. When time permits, I will discuss how we can treat magnetized turbulence near the proton gyro-scale.

Laboratory experiments to study collisionless shocks

Y. Sakawa[1], Y. Kuramitsu[1], T. Morita[1], T. Ide[1], K. Nishio[1], H. Ide[1], K. Tsubouchi[1], K. Tomita[2], K. Uchino[2], N. Woolsey[3], C. Murphy[4], G. Gregori[4], A. Ravasio[5], A. Pelka[5], M. Koenig[5], A. Spitkovsky[6], N. L. Kugland[7], J. S. Ross[7], H.-S. Park[7], B. Remington[7], and H.Takabe[1]

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[2]Kyushu University, Kasuga, Fukuoka, Japan
[3]Department of Physics, University of York, Heslington, UK
[4]Department of Physics, Oxford University, Oxford, UK
[5]LULI, Ecole Polytechnique, Palaiseau, France
[6]Department of Astrophysical Sciences, Princeton University, Princeton NJ, USA
[7]Lawrence Livermore National Lab, Livermore CA, USA

Abstract

Collisionless shocks are often observed in astrophysical plasmas. For example in a shock wave observed in a supernova remnant, a coulomb mean-free-path is much longer than the shock-front thickness. Large amplitude turbulent waves and energetic particles are also observed in the shock environments. Diffusive shock acceleration is considered to be a standard model for non-thermal acceleration of energetic particles or cosmic rays in the universe. A laboratory experiment can be an alternative approach to study collisionless shocks and particle acceleration.

In this paper we investigate laboratory experiments to study collisionless shock generation in counter-streaming plasmas using Gekko XII HIPER laser system (352 nm (3ω), 500 ps, $\sim$100 J/beam, $< 10^{15}$ W/cm^2). The plasmas and shocks were sutdied by optical diagnostics, such as interferometry, shadowgraphy, self-emission measurements, and by Thomson scattering measurements. We also investigate OMEGA and OMEGA EP experimental results to study collisionless shocks, and an experimental proposal to demonstrate the formation of Weibel-mediated collisionless shocks using the National Ignition Facility.

Astrophysical collisionless shocks in the laboratory

H.-S. Park[1], N. L. Kugland[1], J. S. Ross[1], B. A. Remington[1], C. Plechaty[1], D. D. Ryutov[1], A. Spitkovsky[2], G. Gregori[3], A. Bell[3], J. Meinecke[3], C. Murphy[3], Y. Sakawa[4], Y. Kuramitsu[4], H. Takabe[4], D. H. Froula[5], G. Fiksel[5], F. Miniati[6], M. Koenig[7], A. Ravasio[7], E. Liang[8], N. Woolsey[9], R. P. Drake[10], C. Kuranz[10], M. Grosskopf[10], and R. Presura[11]

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[7]Ecole Polytechnique, Paris, France
[8]Rice University, Houston, TX
[9]University of York, Heslington, York, UK
[10]University of Michigan, Ann Arbor, MI
[11]University of Nevada, Reno, NV

Abstract

Most shock waves in astrophysics are collisionless since they form due to plasma instabilities and self-generated magnetic fields. Laboratory experiments at large laser facilities can achieve the conditions necessary for the formation of collisionless shocks, and will provide a unique avenue for studying the nonlinear physics of shock waves. We are performing a series of experiments at the Omega and Omega-EP lasers in Rochester, NY, where collisionless shock conditions will be generated by the two high-speed plasma flows resulting from laser ablation of solid targets using 10kJ to 20 kJ of laser energy. The experiments will aim to answer several questions of relevance to collisionless shock physics: the importance of the electromagnetic filamentation (Weibel) instability in shock formation, the self-generation of magnetic fields in shock collisions, the influence of external magnetic fields on shock formation, and the signatures of particle acceleration in shocks. This paper will present simulations of our experimental conditions; scaling calculations; experimental configurations; and expected results. Our plan for experiments on the National Ignition Facility in Livermore, CA, using up to 1.8 MJ of laser energy will also be presented.

This work was performed under the auspices of the Lawrence Livermore National Security, LLC, (LLNS) under Contract No. DE-AC52-07NA27344; Partial support from the European Research Council is acknowledged.

A simulation study of intracluster turbulence

Dongsu Ryu[1], David H. Porter[2], T.W. Jones[3], and Jungyeon Cho[1]

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National University, Daejeon, Korea
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Abstract

Clusters of galaxies are the largest virialized structures in the universe, which serve as laboratories for the study of astrophysical processes on very large scales. Observations and theoretical arguments suggest that intracluster media is turbulent. The media are very hot and dynamic, highly rarefied, and probably magnetized at some level. The physics involved is complex and high-resolution simulations help us understand the physics and consequent phenomena. We are engaged in a simulation study designed to understand in this context how subsonic turbulence with very weak initial magnetic fields develops and evolves with imposed forcing. We find that the resulting turbulence is sensitive to the nature of forcing as well as the dissipation properties of the media.

Theory and numerical modeling of radiation from sub-Larmor-scale magnetic turbulence

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[1]University of Kansas
[2]Niels Bohr Institute, Copenhagen

Abstract

Spontaneous rapid growth of strong magnetic fields is ubiquitous in high-energy density environments ranging from astrophysical sources and relativistic shocks, to reconnection, to laser-plasma interaction laboratory experiments, where they are produced by kinetic streaming instabilities of the Weibel type. Relativistic electrons propagating through these sub-Larmor-scale magnetic fields radiate in the jitter regime, in which the anisotropy of the magnetic fields and the particle distribution have a strong effect on the produced radiation. We present the general theory of jitter radiation, which includes (i) anisotropic magnetic fields and electron velocity distributions, (ii) the effects of trapped electrons and (iii) extends the description to large deflection angles of radiating particles thus establishing a cross-over between the classical jitter and synchrotron regimes. Our results are in remarkable agreement with dedicated particle-in-cell simulations of the classical Weibel instability. Particularly interesting is the onset of the field growth, when the transient hard synchrotron-violating spectra are common, which can serve as a distinct observational signature of the violent field growth in astro sources and lab experiments. It is also interesting that a system with small-scale magnetic turbulence fields tends to evolve toward the small-angle jitter regime.

Radiation hydrodynamics of supernova shock breakouts

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Abstract

The first powerful burst of photon radiation in a supernova appears when the shock front is a few photon mean-free paths below the star photosphere. This is called "shock breakout" and it is the first observable event after the neutrino and gravitational wave bursts in core-collapsing supernovae. Any early information about collapse is vitally important for understanding the physics of explosion, constraining speed of neutrino propagation etc. We witness direct observations of shock breakouts in a few supernovae. I will discuss some puzzles related to those objects. The theory must be developed here and this may lead eventually to better understanding of presupernova stars and physics of strong radiative shocks. Finally, I describe our current understanding of the most luminous subtype II supernovae (SN IIn). The potential use of their long living radiative shocks as a tool for measuring distances and cosmological parameters without invoking the distance ladder will be discussed.

Diverging core-collapse supernova experiments on NIF

Tomasz Plewa[1], Michael Grosskopf[2], Hye-Sook Park[3], Paul Keiter[2],
R. Paul Drake[2], Carolyn C. Kuranz[2], Tim Handy[1], Markus Flaig[1],
Bruce Remington[3], Aaron Miles[3], and Kumar Raman[3]

[1]Florida State University
[2]University of Michigan
[3]Lawrence Livermore National Laboratory

Abstract

We present a computer-based design of an experiment relevant to core-collapse supernovae (ccSNe), using a spherically diverging system with two or more interfaces. The mass of the layers between the interfaces is scaled to actual values from models of SN 1987A, as accumulated mass is the key parameter for blast wave dynamics and blast-wave-driven instabilities. The structure on the interfaces is based on the simulation and analysis of structure in presupernova stars. The design builds on our previous work at Omega, which proved insufficient to drive a massive hemi-spherical target. Currently NIF is the only existing experimental facility that can accomplish the proposed experiment and produce mixing in a diverging, multi-layer system relevant to ccSNe.

To simulate the experimental systems we use a multiphysics fluids code, CRASH, developed at the Center for Radiative Shock Hydrodynamics at the University of Michigan. The CRASH code is equipped with a laser energy deposition package that allows for generating the initial conditions including time-dependent laser-driven structure of the flow entering computational domain, in multiple dimensions. Using CRASH, we perform a series of numerical experiments to assess sensitivity of the model to numerical diffusion, target fabrication errors, and variation in laser drive parameters. We also briefly discuss a possible contribution due to magnetic fields.

The acceleration and escape of particles in young supernova remnants

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[2]DESY
[3]Universitat Potsdam

Abstract

Combining numerical simulations of supernova remnant (SNR) evolution with a solution of the cosmic-ray transport equation in test-particle mode, we study the acceleration of particles at forward and reverse shocks in both Type Ia and core-collapse SNRs. We include the effect of various magnetic field profiles in the shocked interaction region. We study the temporal evolution of the non-thermal particle distribution, and synthesize surface brightness maps for various radiation mechanisms. We investigate how the spectrum of escaped particles depends on the time-dependent acceleration history in young SNRs, and calculate the time-dependent gamma-ray spectra from molecular clouds illuminated by the escaping cosmic-rays.

Spontaneous deflagration-to-detonation transition in thermonuclear supernovae

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Abstract

Type Ia supernovae (SN Ia) were first suggested over half a century ago to be the result of the thermonuclear incineration of a degenerate white dwarf star (WD) with a mass near the Chandrasekhar limit in a binary stellar system. Presently, the scenario best capable of explaining the observational properties of "normal" SNIa, which are of primary importance for cosmology, is the delayed-detonation model. In this model, the explosion starts as a subsonic deflagration that later transitions to a supersonic detonation (deflagration-to-detonation transition, or DDT). It remains unclear, however, whether DDT can indeed occur in the interior of a WD, and what the mechanism of this transition could be. Modern large-scale multidimensional simulations of SNIa cannot capture the DDT process and, thus, are forced to make two crucial assumptions, namely (a) that DDT does occur at some point, and (b) when and where it occurs. Furthermore, the nature of the unconfined DDT in systems without walls or boundaries remains unknown even in the context of chemical flames on Earth. Here we show, through fully resolved first principles numerical simulations, that at sufficiently high turbulent intensities, subsonic turbulent flames in such unconfined environments are inherently susceptible to the DDT. The associated mechanism is qualitatively different from the traditionally suggested gradient (spontaneous reaction wave) model. It also does not require the formation of distributed flames. The proposed mechanism predicts the DDT density in SNIa to be $\sim 10^7$ g/cm^3, in agreement with the values that were previously found to give the best match with observations. We discuss the implications of this mechanism for SNIa as well as the possibilities for its validation in terrestrial laboratory experiments.

Confronting stellar structure theory with asteroseismic data

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Abstract

The theory of stellar structure and evolution is one of the better established theories in astrophysics. The simplicity of the theory, and its ability to explain the observations of star clusters as well as field stars ensured its success. Till very recently the only observations the theory of stellar structure was confronted with dealt with the properties of the stellar surface such as surface temperature, metallicity and luminosity. We now have observations of stellar pulsations from missions like Kepler. The pulsations probe the interior of stars. These allow us to determine properties of stars in a manner not possible earlier. These observations could also allow us to reduce some of the uncertainties inherent in the theory. The study of solar pulsations has already helped us put constrains on some of the inputs to the theory, and we should soon be able to put constraints on stellar models as well. In this talk I shall review how we use these data to constrain stellar models and some new results that we have obtained.

The dynamics of arched, plasma-filled magnetic flux tubes

Eve Stenson[1] and Paul Bellan[1]

[1]Caltech

Abstract

The solar corona is home to a vast array of arched plasma structures (e.g., solar coronal loops and prominences) that are magnetically linked to a conducting boundary. These structures can exhibit rapid dynamic evolutions. Laboratory plasma experiments at Caltech provide a means to study the basic physics of these events, while offering the benefits of reproducibility, diagnostic accessibility, and parameter tuning.

The experiments show that the evolution of an individual arched, plasma-filled magnetic flux tube is governed by two complementary MHD-driven processes. The first process is the hoop force, which transforms a small, semi-circular tube of plasma into a much larger "loop"; the length of the arched flux tube typically increases five- to seven-fold. The second process is the acceleration of bulk flows along the flux tube axis. The flows originate from both footpoints, carry plasma toward the apex of the plasma loop, and maintain both the density and the collimation of the flux tube during its dramatic lengthening.

Both processes scale in proportion to an "azimuthal Alfven speed" $B_\phi/(\mu_o\rho)^{1/2}$, where B_ϕ is the magnetic field due to the electrical current flowing along the flux tube. This has been demonstrated in laboratory experiments by such means as varying the plasma mass density with the use of different ion species (sometimes within the same loop), and increasing or decreasing the azimuthal magnetic field. Because MHD has no intrinsic length scale, it is expected that the same physics occur in magnetic flux tubes in the solar corona.

Clumps with self contained magnetic field and their interaction with shocks

Shule Li,[1], Adam Frank,[1], and Eric Blackman[1]

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Abstract

Problems involving magnetized clouds and clumps, especially their interaction with shocks are common in astrophysical environments and have been a topic of research in the past decade. Many previous numerical studies have focused on the problem of clumps immersed in a globally uniform magnetic field subject to a oncoming shock. However, realistic clumps may have tangled magnetic field self contained within them. This magnetic field will be compressed by the shock and its energy spectrum and spatial structure may affect the evolution of the clump during the shock encounter. Using our parallel MHD code AstroBEAR, we set up an initial state with magnetized clumps of different contained magnetic field configurations, study their interaction with shocks, and compare them to the previous studied global uniform field scenario.

On the possibility of a two dimensional, multimode RM experiment on EP

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Abstract

The Richtmyer-Meshkov (RM) [1,2] process occurs when a shock wave passes through an interface separating two materials with different densities, and deposits vorticity on it, in consequence of structures on the interface and/or the shock front. As a result of the vorticity deposition, the initial structure grows in time, linearly for initial modulations of small amplitude and in a decaying fashion as the amplitude increases. This process also occurs when astrophysical shock waves cross density gradients. It has been suggested that RM is responsible for the observed structure in the remnant of the Tycho thermonuclear supernova [3]. Since the initial experiments of Meshkov [2], there have been a large number of RM experiments done in shock tubes, focused on the behavior of a single sinusoidal mode or a two mode interaction [4,5]. Previous HED RM experiments using machined interfaces have examined only single-mode behavior, often in the regime of high Mach number and large amplitude such that the interaction of the RM spikes and the shock is significant [6]. In the case of multi-mode initial perturbations, non-linear processes of mode coupling and equivalently bubble competition are dominant. In the bubble competition process, large bubbles overtake the volume originally occupied by smaller bubbles. Due to this mechanism, the average wavelength of the multi-mode perturbed interface increases with time and the width of the overall "mixing zone" grows faster than in the case of a single-mode interface. At late time the mixing zone is theorized to become self-similar and to grow as t^{θ}, where θ =0.2 for a three-dimensional [7] flow and $\theta =$ 0.4 for a two-dimensional flow [8] for the bubble front and in the range of $0.2 - 1$ for the spike front, depending on the Atwood number. Although there have been studies of RM using three dimensional multimode, uncharacterized perturbations, allowing one to reach conclusions only about the thickness of the overall "mixing zone", none of the prior work has examined the evolution of a well-characterized, multimany-mode interface in order to observe the evolution of the spectral structure in the "bubble-merger" regime. In the present study, we propose to undertake that, doing experiments that are enabled by the ability of Omega EP to drive targets for several times larger than was feasible on previous high-energy lasers.

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What does it take to launch jets from accretion discs?

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Abstract

Well collimated jets are observed from young forming stars, active galactic nuclei and some galactic compacts objects. These jets are powerful in the sense that they seem to carry a sizable fraction of the power released in the underlying accretion disc. The most reliable models relate therefore accretion to ejection, through the action of large scale magnetic fields anchored in the rotating disc (and maybe in the central object as well).

In this talk, I will first recall the successes (and open issues) of these MHD models. Some emphasis will be put on the comparison with observations of jets from young stars. Indeed, these jets are well monitored, with several diagnostics and their observed kinematics put stringent constraints on jet models.

On the other hand, other astrophysical systems such as X-ray binaries display a complex behavior in time that remains unexplained yet. I will then briefly present these systems and argue that their complexity could be the sign of the interplay between field diffusion and advection within the outbursting disc.

Comparing Poynting flux dominated magnetic towers with kinetic-energy dominated jets

Martín Huarte-Espinosa[1], Adam Frank[1], Eric G. Blackman[1],
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[4]Rice University, Department of Physics and Astronomy, Houston, TX
[5]The Blackett Laboratory, Imperial College London

Abstract

Magnetic towers represent one of two fundamental forms of MHD outflows. Driven by magnetic pressure gradients, these flows have been less well studied than magneto-centrifugally launched jets even though magnetic towers may well be as common. In this talk we present new results exploring the behavior and evolution of magnetic tower outflows and demonstrate their connection with pulsed power experimental studies. High-resolution AMR MHD simulations (using the AstroBEAR code) provide insights into the underlying physics of magnetic towers and help us constrain models of their propagation. Our simulations have been designed to explore effects of thermal energy losses and rotation on tower flows. In addition we also explore the effect of the Poynting-to-kinetic energy flux ratio and toroidal-to-poloidal magnetic flux ratio. We find these parameters have significant effect on the stability of magnetic towers. Current-driven perturbations in the Poynting Flux Dominated (PDF) towers are shown to be amplified in both the cooling and rotating cases. Our studies of the the long term evolution of the towers show that the formation of weakly magnetized central jets within the tower are broken up by these instabilities becoming a series of collimated clumps whose magnetization properties vary over time. In addition to discussing these results in light of recent laboratory experiments we also show their relevance to astrophysical observations of young star jets and outflow from highly evolved solar type stars.

Magnetic field generation and particle acceleration in relativistic shear boundary layers

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Abstract

We will report exciting new results of Particle-in-Cell Simulations of relativistic shear flows. We obtain efficient generation of ordered magnetic fields and nonthermal particle acceleration at shear boundary layers. The peak fields reach approximately equipartition values and are sustained by the free energy and vorticity of the shear flow. The nontheraml particles are accelerated by cross field electric forces, thus emitting synchrotron radiation efficiently. We will discuss the astrophysicsl implications for blazar and gamma-ray burst jets. We will also briefly describe some conceptual designs of laboratory experiments using ultraintense lasers.

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Laboratory observations of magnetic reconnection resulting from multiscale instability cascade

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Abstract

Magnetic reconnection underlies critical dynamics in many astrophysical plasma systems. Because observed reconnection rates are often significantly higher than those predicted by classical resistivity, most modern theories instead attribute the necessary diffusion to a combination of processes that take place on scales 'microscopic' compared to the scale of ideal MHD. This leaves unanswered the question of how a system can couple the ideal MHD scale to the microscale necessary for reconnection. A laboratory plasma experiment at Caltech demonstrates one possible mechanism: an instability of an instability. The experiment produces a collimated, magnetically driven plasma jet ~ 25 cm long, with density $n \sim 10^{21-22}$ cm^{-3} and temperature $T \sim 2$ eV. The current-carrying jet undergoes an ideal MHD kink instability which then drives a secondary Rayleigh-Taylor instability. High-speed imaging shows that if the Rayleigh-Taylor instability succeeds in eroding the plasma diameter to a sufficiently 'microscopic' scale (ion skin depth), the plasma undergoes magnetic reconnection.

Interaction of high Mach-number shocks in laser-produced plasmas

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Abstract

Shock waves are known to be important for particle accelerations and thermalization of plasmas both in the universe and in space plasmas. Therefore, they have been studied theoretically, numerically, and observationally for many years. The interactions of two shocks and of a shock with an interface where density increases are also commonly observed. Shock collisions, for example, occur between forward and reverse shocks at solar winds [1] and between an interplanetary shock and Earth's bow-shock [2]. Shock-interface interactions are observed in molecular clounds when supernova remnant shocks propagate them [3]. These interactions are also important for paticle acceleration and plasma heating. High Mach-number shocks have been produced with high-power laser systems [4,5] to investigate a single collisionless shock. We observed multiple shock interactions in temporal evolution data of the plasma expansion and shock propagation. Shock collisions were measured with optical probe diagnostics and streaked emission measurements. These results show clear jumps of emission brightness and plasma density at regions where shocks interact. We discuss the possibility of model experiments for strong shock formations and shock interactions as observed in the universe and in space plasmas using a high-power laser.

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Scaling astrophysical radiation hydrodynamics for the laboratory

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Abstract

In this presentation scaling laws (SL) connecting astrophysical radiation hydrodynamic phenomena to those created in laboratory with high energy/power facilities are examined. The traditional approach for SL is based on the use of dimensionless numbers and the invariance of their numerical values from a first phenomenon to a second one (Sedov 1946). This procedure is especially relevant when the physical processes under study are very complex and such that the equations for a mathematical model are not known. In contrast, when the equations governing the process can be derived, their invariance under Lie groups (Lie 1888, 1890 and 1893) provides a rigorous approach to get the appropriate SL although it is mainly used for the analytical integration of differential equations (DE) up to now (Ovsjannikov 1962, Bluman and Cole 1974, Ibragimov 1985, Olver 1986). Nevertheless, in laboratory astrophysics, invariance of the DE of the model has been performed to get scaled laboratory simulations of astrophysical phenomena in several areas ranging from supernova hydrodynamics to the interaction of strong electromagnetic fields with plasmas (Ryutov et al. 1999 and 2009, Ryutov et al. 2000, Ryutov et al. 2001, Ryutov and Remington 2002, 2003, 2006 and 2007). On the other hand, Takabe (Takabe 2001) provided a qualitative classification of similarity criteria based mainly of physical argumentations. In our presentation, the two aspects, i.e. physical and mathematical, are used together in order to derive a hierarchy of SL obtained from various constraints on the degree of invariance of the DE (Bouquet et al. 2010, Falize et al. 2011) and in the less constraining cases additional degrees of freedom can appear making easier the production of a laboratory plasma that can be similar to the astrophysical process. This approach is illustrated on a few examples of astrophysical radiation hydrodynamics (radiative shocks, young stellar jets etc.).

Fast magnetic reconnection in high-energy-density laser-produced plasmas

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[1]University of New Hampshire

Abstract

Recent experiments have observed magnetic reconnection in high-energy-density, laser-produced plasma bubbles, with reconnection rates observed to be much higher than can be explained by classical theory. This is a novel regime for magnetic reconnection study, characterized by extremely high magnetic fields, high plasma beta and strong, supersonic plasma inflow. We use particle-in-cell simulations (with collision operator) to study reconnection in this regime with geometry and parameters relevant to the experiments. These simulations have identified two key ingredients, simultaneously present for the first time: two-fluid reconnection mediated by collisionless effects (that is, the Hall current and electron pressure tensor), and strong flux pile-up of the inflowing magnetic field. These effects combine to yield reconnection rates independent of the nominal Alfvén speed (based on the magnetic field before interaction), and simply given by the dynamic time L/V, in qualitative agreement with the experiments. We present simulations spanning the parameter ranges of the experiments, including the role of binary collisions. We conclude with a discussion of proposed future laser-driven reconnection experiments.

Laser produced high density plasmas

Yong-Joo Rhee[1], Hiroaki Nishimura[2], Shinsuke Fujioka[2], Dimitri Batani[3], Joao Santos[3], Michel Koenig[4], Sophie Baton[4], Jan Badziak[5], and Petra Koester[6]

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Abstract

Recently applications of high energy lasers to the study of high energy density sciences such as laser fusion, X-ray spectroscopy of stellar objects, high speed plasma jets of prostars and so on are widely carried out.

In this presentation brief introduction to the experiments at some laser facilities are given, followed by comparison of numerical simulations of those plasmas. Simulations of plasmas of the experiments at LULI (France) and LLNL (USA) for electron transport in 1D compressed plasmas, those at RAL (UK) for electron transport and radiography in 2D compressed plasmas, those at ILE (Japan) for photoionization of Si plasma by X-rays from 3D compressed plasmas, and those at PALS (Czech Republic) for plasma acceleration in a narrow channel would be discussed.

Investigating Mix in Colliding-Shock Experiments

Kirk Flippo[1], Dustin Offermann[1], Eric Loomis[1], Leslie Welser-Sherrill[1], Jim Fincke[1], and Nick Lanier[1]

[1]Los Alamos National Laboratory

Abstract

Experiments have been performed at the Omega laser facility to investigate turbulence-driven mix from two colliding shocks, such as expected in ICF ignition capsules. Two shocks were generated at either end of a cylindrical, CH foam. The evolution of an Al tracer layer at one end of the foam was measured using point-projection radiography. Comparison of this data with simulations from the code, RAGE has been done to improve its predictive capability for ICF experiments. RAGE implements the Besnard-Harlow-Rauenzahn (BHR) model, which is intended for turbulent transport in fluids with large density variations.

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Numerical simulations of Z-Pinch experiments to create supersonic differentially rotating plasma flows

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Abstract

In the context of laboratory astrophysics relevant to accretion discs physics, we aim to study possible setups for a plasma experiment employing pulsed power machines. We carry out our study through direct numerical simulations using the 3D MHD code GORGON. It is found that the setups, based on a modified cylindrical wire array, produce a rotating plasma with typical Mach number about 4, rotation velocity about 30 km/s, Reynolds number in excess of 10^7 and magnetic Reynolds number of order 1. The plasma is also differentially rotating. The physical parameters of the flow can be varied by properly tuning the setup. Such plasma is particularly interesting for the study of hydrodynamic instabilities relevant to accretion discs and turbulence in differentially rotating flows with high Reynolds number. The material of the rotating flow is ejected in a pair of thermally driven, conical outflows propagating along the rotation axis. This behavior can be compared to some accretion-ejection circulation models for protostars. Different external magnetic field topologies have been tested. A modest uniform vertical field can affect the dynamics of the flow and could be used to study magnetic field entrainment and amplification through differential rotation. A dipolar field potentially relevant to the study of accretion columns and its experimental feasibility are also discussed.

The art of designing and fielding relevant HEDP experiments

Bernhard H. Wilde[1]

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Abstract

Over the past 20 years I have been involved in over 500 HEDP and ICF experiments performed on the NOVA, OMEGA, and NIF lasers and on the Z pulsed power machine. These experiments investigated hydrodynamic shocks and jets, radiation hydrodynamics, opacities, laser plasma instabilities, etc. This talk will discuss my view of what makes a successful HEDP experiment. That is, what in the design and fielding of these experiments makes them successful and relevant and what causes failures.

FLASH simulations of experiments to explore the generation of cosmological magnetic fields

M. Fatenejad[1], A.R. Bell[2], A. Benuzzi-Mounaix[5], R. Crowston[6], R.P. Drake[4], N. Flocke[1], M. Koenig[3], C. Krauland[4], D. Lamb[1], D. Lee[1], J.R. Marques[3], J. Meinecke[2], F. Miniati[5], C.D. Murphy[2], H.-S. Park[7], A. Pelka[3], R. Pierson[4], A. Ravasio[2], B. Remington[7], B. Reville[2], A. Scopatz[1], P. Tzeferacos[1], K. Weide[1], N. Woolsey[6], and R. Yurchak[3]

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[6]The University of York
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Abstract

The FLASH center is engaged in a collaboration to simulate laser driven experiments aimed at understanding the generation and amplification of cosmological magnetic fields using the FLASH code. In these experiments a laser strikes a solid plastic or graphite target launching an asymmetric blast wave into a chamber which contains either Helium or Argon at millibar pressures. Induction coils placed several centimeters away from the target detect large scale magnetic fields on the order of tens to hundreds of Gauss. The time dependence of the magnetic field is consistent with generation via the Biermann Battery mechanism near the blast wave (G. Gregori, Nature, v. 481, p. 480, 2012). We will discuss several challenges faced in simulating this novel experiment and report results from an ensemble of radiation-hydrodynamic simulations that reveal unexpected features of the experiment which may affect the magnetic field generation.

Turbulent Mixing at the High Re Limit: V&V/UQ

James Glimm[1]

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Abstract

Validated numerical simulations of turbulent mixing will be presented, based on the Front Tracking/LES/Dynamic Subgrid Scale method. Both macroscopic and molecular level mixing variables will be studied, including joint probability distribution functions of fluctuating fluid variables. Theoretical arguments and numerical exidence are presented for the existence of a two parameter family of mixing solutions in the high Reynolds number limit. These solutions are universal relative to modification of physical diffusive transport processes; the convergence is slow for thermal effects in the case of a plasma like fluid. The two parameter family is labeled by turbulent Schmidt and Prandtl numbers (selected in a theoretically determined manner by the dynamic SGS model). It is sensitive to choice of the turbulent subgrid stress models or to numerical methods which mimic these effects through algorithmic choices. A series expansion for the Reynolds stress and related SGS terms will be given based on Renormalization Group ideas.

A weighted essentially nonoscillatory Implementation of a Reynolds-averaged Navier-Stokes model for Richtmyer-Meshkov instability-induced Mixing

J. Tiberius Morán-López[1], James P. Holloway[1], and Oleg Schilling[2]

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Abstract

A high-order, multicomponent, weighted essentially nonoscillatory (WENO) implementation of a two-equation K-ϵ Reynolds-averaged Navier-Stokes model is used to simulate reshocked Richtmyer-Meshkov turbulent mixing at various Atwood and Mach numbers. The predicted mixing layer evolution is compared with several experimental data sets, as well as with analytical late-time self-similar solution of the transport equations. The sensitivity of the turbulence model solutions and transport equation budgets to variations in the initial conditions, variations in the key model coefficients, and order of flux reconstruction (third- and fifth-order) is explored. In addition, the convergence properties of the solutions is examined as the grid is refined in space.

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Effects of magnetic fields on photoionised pillars of dense gas

Jonathan Mackey[1,2] and Andrew J. Lim[2]

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[2]Dublin Insitute for Advanced Studies, Dublin, Ireland

Abstract

I will first introduce the photoionisation-magnetohydrodynamics code I have developed, and will discuss the efficiency and parallel scaling of implicit and explicit raytracing-photoionisation integration algorithms. I will then describe 3D simulations we performed to investigate the effects of initially-uniform magnetic fields on the formation and evolution of dense pillars and cometary globules at the boundaries of HII regions. For weak and medium field strengths an initially perpendicular field is swept into alignment with the pillar during its dynamical evolution, matching magnetic field observations of the "Pillars of Creation" in the Eagle Nebula (M16) and also some cometary globules. A strong perpendicular magnetic field remains in its initial configuration and also confines the photoevaporation flow into a bar-shaped dense ionised region which partially shields the ionisation front and would be readily observable in recombination lines. The results show that ISM magnetic field strengths can in principle be constrained by the morphology of ionised and neutral gas structures in HII regions.

Theory and experiments of accretion processes in cataclysmic variables

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Abstract

The accretion processes are among the most important phenomena in high-energy astrophysics since they are widely believed to provide the power supply in numerous astrophysical objects and are the main source of radiation in binary systems containing compact objects. Among the different X-ray binary systems, the cataclysmic variable (CV) stars provide a unique insight in order to study the accretion processes in extreme astrophysical regimes. They are close binaries containing a white dwarf (WD) which accretes matter from its late-type low mass main sequence companion [1]. Their importance is due to the fact that they provide the best opportunity to study the accretion processes in isolation, since other sources of luminosity (mainly the WD and the secondary star luminosity) are relatively unimportant or well known. CVs are divided in two main classes. For the nonmagnetic CVs, the accretion occurs through an accretion disc and for the magnetic CVs (mCVs), the accreted plasma is directly guided by the magnetic field lines down to the magnetic poles of the white dwarf.

During this talk, we will detail the accretion processes in the two classes of CVs and we will focus on the high-energy environment near the photosphere of the compact objects for mCVs. The understanding of the physics of this region is fundamental since it is at the basis of the determination of the WD properties [2]. In the standard model, the impact of

the supersonic free-fall accreting matter with the WDâs photosphere generates a shock (accretion shock) [3], which heats the infalling plasma up to 10-50 keV. This post-shock region cools by different radiative processes that lead to the formation of high-stratified structure in temperature and density [2]. Unfortunately, the size scales associated with these zones are on the order of the WD radius or smaller, which avoid their direct observations and the determination of the physics of the impact zone [4]. For this reason, every alternative approach that can provide a direct insight of these objects is of primary importance. Recently, exact scaling laws have been calculated for this accretion column scheme in different accretion regimes and demonstrated that we can reproduce these physical regimes with powerful lasers [5], [6], [7]. A review concerning these experimental results will be presented demonstrating the possibility to study efficiently the radiation hydrodynamics accretion processes in laboratory.

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Reverse radiative shock laser experiments relevant to accreting stream-disk impact in interacting binaries

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Abstract

In nonmagnetic cataclysmic variable (CV) systems, mass transfer via Roche lobe overflow onto an accretion disk occurs. The supersonic impact of the infalling matter with the rotating accretion disk can produce a radiative reverse shock, known as a 'hot spot'. This collision region has many ambiguities as a radiation hydrodynamic system. Depending upon conditions, it has been argued (Armitage & Livio, 1998, ApJ, 493, 898) that the shocked region may be optically thin, thick, or semi-transparent, which has the potential to significantly alter its structure and emission.

We present the results from high-energy-density laboratory astrophysics experiments that explore the hydrodynamic and radiative properties of a reverse shock relevant to such CV systems. In this context, a reverse shock is a shock wave that develops when a freely flowing, supersonic plasma is impeded. In our experiments, performed on the Omega laser facility, a laser pulse is used to accelerate a Sn plasma ejecta through vacuum into an Al plate in front of which a shock forms in the rebounding plasma. We will discuss the experimental design and available data with complementing CRASH (van der Holst et al., 2011, ApJS, 194, 23) simulations.

Funded by the NNSA-DS and SC-OFES Joint Prog. in High-Energy-Density Lab. Plasmas, by the Nat. Laser User Facility Prog. in NNSA-DS and by the Predictive Sci. Acad. Alliances Prog. in NNSA-ASC, under grant numbers are DE-FG52-09NA29548, DE-FG52-09NA29034, and DE-FC52-08NA28616.

Recent advances in the experimental simulation of X-ray binary stars accretion shocks

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Abstract

The capability to produce in laboratory radiation hydrodynamic flows relevant to high-energy astrophysical environments is a real opportunity to progress in their modeling. Recently we have proposed an original approach which allows to study the radiative accretion shocks in magnetic cataclysmic variables. Using an adapted target design, we can explore, test and constraint different aspects of their specific physics.

In this work we will present the recent theoretical and experimental works and the connection with astronomical observations. The first similarity results will be extended to the set of physical regimes of the radiative accretion column: from the different accretion shock regimes to the bombardment regime. The link with laboratory astrophysics experiments, and specifically the opportunity opened by the Megajoule facilities, will be discussed in detail.

Simulating the long-term evolution of radiative shocks in shock tubes

Bart van der Holst[1], Gabor Toth[1], Igor Sokolov[1], Ben Torralva[1],
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Abstract

We present the latest improvements in the Center for Radiative Shock Hydrodynamics (CRASH) code, a parallel block-adaptive-mesh Eulerian code for simulating high-energy-density plasmas. The implementation can solve for radiation models with either a gray or a multigroup method in the flux-limited-diffusion approximation. The electrons and ions are allowed to be out of temperature equilibrium and flux-limited electron thermal heat conduction is included. We have recently generalized the CRASH laser package to 3D ray tracing, resulting in improved energy deposition evaluation. New, more accurate opacity models are available which significantly improves radiation transport in materials like xenon. In addition, the HYPRE preconditioner has been added to improve the radiation implicit solver. With this updated version of the CRASH code we will demonstrate radiative shock tube problems. In our set-up, a 1ns, 3.8kJ laser pulse irradiates a 21 micron beryllium disk, driving a shock into a xenon-filled plastic tube. The electrons emit radiation behind the shock. This radiation from the shocked xenon preheats the unshocked xenon. Photons traveling ahead of the shock will also interact with the plastic tube, heat it, and in turn this can drive another shock off the wall into the xenon. We are now able to simulate the long term evolution of radiative shocks and compare with X-ray radiographs obtained from shock tube experiments at the Omega high-energy-density laser facility.

Experimental investigations into what open-field line, current-carrying, magnetized plasmas really do

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Abstract

Although magnetohydrodynamics (MHD) is presumed to be a fairly mature subject, experimental investigations continue to reveal remarkable new insights into how MHD really works.

The Caltech experimental research program has demonstrated that certain widely used MHD paradigms are either inappropriate or somewhat misleading. These paradigms date from the early days of fusion research when it was assumed that (i) a plasma could be considered to be in a static MHD equilibrium and (ii) there could be stable or unstable Fourier mode perturbations about this equilibrium. Another paradigm has been to assume that if the plasma has low beta, its behavior can be reasonably described by ignoring pressure gradients.

What has been found is that when electric current flows along open magnetic field lines, the presumed static equilibrium typically does not exist and instead complex non-equilibrium dynamics occur. The plasma progresses through a sequence of non-equilibrium configurations involving strong unbalanced MHD forces causing high-speed plasma flows. These flows convect the frozen-in magnetic flux associated with the magnetic field produced by the electric current. This magnetic field provides a plasma-confining pinch force and so produces substantial pressure gradients. The pinched flow is thus a collimated, MHD-driven plasma jet. The jet is neither static nor in equilibrium because it is lengthening. Despite not being in static equilibrium, the jet can develop MHD kink instabilities because the kink grows on a faster time-scale than the jet characteristic time. Hence kink instability is not restricted to static equilibria but is also an important feature of dynamically changing, non-equilibrium plasmas.

Most recently, it has been observed that (i) the kink itself can become unstable to a finer-structure, much faster instability (instability of an instability) that suddenly rips the jet apart and (ii) when current flows along a magnetic flux tube bulged at its axial midpoint, MHD forces drive axial plasma jets from both ends towards the axial midpoint. These effects are observed using high-speed imaging systems that capture the plasma evolution on the Alfven time scale.

Supported by USDOE, NSF, and AFOSR

Investigations of bow-shock formation in radiatively-cooled supersonic plasma flows

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Abstract

The development of shocks in plasma flows occurs in a wide range of environments, particularly in astrophysical systems. In wire array experiments, the plasma accelerated from the wire via the Lorentz force rapidly exceeds both the local sound and Alfven speeds, providing an interesting source for shock studies. Recently, the plasma flow in a 1 MA wire array z-pinch demonstrated both the formation of bow shocks around an obstacle in the plasma, and the feasibility of testing the effect of magnetic fields and radiation cooling on the shock formation in these systems [1].

We present a new project which examines bow shock formation in wire array plasma flows. The plasma densities produced ($n_e \sim 10^{17}$ - 10^{19}cm^{-3}) are sufficiently low to allow continuous 2-dimensional quantitative measurements of the electron density, whilst remaining in the collisional (hydrodynamic) regime. A close examination of the shock structure and evolution is therefore possible, and results are compared with both analytical theory and simulation work. By changing the wire material, the effect of the radiative loss rate on the shock structure can be directly evaluated. Data from recent experiments will be presented and discussed, along with future plans to include B-fields into the shock region.

Work is supported by Dept of Energy, Office of Fusion Energy Sciences under contract DE-SC0006958.

[1] D. J. Ampleford et al, Phys. Plasmas, 17, 056315 (2010)

POLAR Project: numerical modeling of the accretion column

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Abstract

Polars, also called magnetic cataclysmic variables, are binary systems containing a highly magnetized white dwarf accreting material from a Roche lobe-filling companion. The white dwarf magnetic field forces the flow to follow field lines when leaving the inner L1 Lagrange point preventing the formation of an accretion disk. Material is led directly toward magnetic pole where it forms accretion column.

Most of radiation coming from those systems is emitted in a narrow region close to the basis of the column and shows spectroscopic clues of the presence of shocks in the accreted material. This region undergoes numerous processes of high-energy density physics, which makes it particularly interesting to study.

A hydrodynamical code, Hydro-Cool, has been developed in order to deal with high Mach number flow and is currently improved to produce a numerically modeled accretion column. New numerical results will be presented as well as a discussion about the non-stationary evolution of the column. Links with the laboratory experiment of the POLAR project will also be presented.

POLAR Project: latest experimental results and prospects

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Abstract

Considering modern high energy density facilities, bringing up matter to extreme states of density, temperature and velocity relevant to astrophysics is reproducibly achievable. New similarity experiments in the POLAR Project take advantage of this opportunity to study the formation and dynamics of accretion shocks as found in magnetic cataclysmic variables, also called polars. Rigorous scaling laws proved that relevant regime could be reached.

At the astrophysical scale, the system we consider is a column of infalling plasma on the surface of a white dwarf. This column is collimated by the magnetic field of the compact star. As matter hits the surface with supersonic velocity, a shock appears at the basis of the column and propagates upstream. In laboratory, a flow of plasma is produced using laser-matter interaction, a tube collimates it and an obstacle of quartz mimics the surface of the white dwarf.

We have recently tested the experimental concept and first results are promising. The target design is currently improved, for example we try to increase the mass of material available for the reverse shock to propagate through. Latest results from the experiment will be presented along with numerical simulations.

Laser-Compton scattering as a backlighter X-ray source

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Abstract

X-ray backlighters have numerous applications in inertial confinement fusion and high energy density experiments. They are powerful diagnostic tools for imaging short lived phenomena in high density materials. In order for an x-ray source to be a useful x-ray backlighter, this source must be bright with an intensity of the order of 10^9 photons/sr, a high signal to noise ratio for high image contrast, low spectral background, tunable with x-ray energies ranging from 20 to 100 keV or higher, spectrally resolved and high spatial resolution. An alternative to laser-produced x-ray sources could be laser-Compton scattering (LCS) where a relativistic electron bunch interacts with high power laser pulse. The advantages of such a source for inertial confinement fusion and high energy density (HED) studies are many fold. LCS x-ray source is virtually free of incoherent bremsstrahlung radiation. It is highly collimated in the direction of the incident electron beam with an opening hal f angle equal to 1/gamma. LCS x-ray energy is continuously tunable with x-ray energy ranging from soft x-rays to hard x-rays. LCS x-ray source size can be made as small as a few tens of microns therefore suitable for phase contrast imaging and can deliver pico or sub-picosecond x-ray bursts ideal for recording short snap shots of short lived phenomena.

Design of an experimental platform for jet-ambient interaction studies

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Abstract

The formation and evolution of shock structures and density non-uniformities along the jets from young stellar objects (YSOs) [1] provides insight into the basic fluid dynamics of collimated, radiatively-cooled supersonic flows. Pulsed power driven jets (conical/radial wire arrays; radial foils [2,3]) have appropriate dimensionless parameters (Mach number; Reynolds number; cooling parameter) to simulate aspects of this class of astrophysical jets under controlled conditions. In order to model YSO interaction dynamics we require a target plasma with density of the same order of magnitude as that of the jet. In our previous experiments gas cloud [4] and ablation of a plastic target [5] provided an ambient medium for jet interaction/deflection studies. In this paper we present a novel experimental configuration to propagate plasma jets into precursor plasma in a cylindrical wire array. Magnitude and distribution of density in the target plasma are selected by varying array diameter and wire number. It is found that this configuration enables user-friendly selection of interaction length and target density and preliminary results will be presented illustrating the influence of target density and jet material on the flow dynamics of conical wire array jets.

[1] Hartigan et al. 2011, ApJ, 736, 29
[2] Lebedev et al. 2002, ApJ, 564, 113-119
[3] Ciardi et al. 2009, ApJ, 691, L147-L150
[4] Suzuki-Vidal et al. 2012, PoP, accepted
[5] Lebedev et al. 2004, ApJ, 616, 988-997

Extraction of temperature in a laboratory photoionized plasma experiment at Z

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Abstract

We report on a method to extract the electron temperature of a laboratory photoionized neon plasma produced in Z experiments at Sandia National Laboratories based on the population ratio of two energy levels close in energy. Preliminary studies revealed evidence of dominant electron collisional excitation and de-excitation over photo-excitation and spontaneous radiative decay between the $1s^22p$ and $1s^22s$ levels. Since the populations of these levels were determined from the analysis of transmission spectra, it was then possible to estimate the temperature via a Boltzmann factor. Further studies were performed for various plasma conditions such as temperature and density in order to confirm the reliability of the method. Calculations were performed for a sequence of steady states and in a full time-dependent mode. The neon atomic kinetics model considers several ionization stages of neon ions as well as a detailed structure of non-autoionizing and autoionizing energy levels in each ion. Atomic processes populating and de-populating the energy levels consider photoexcitation and photoionization due to the external radiation flux, and spontaneous, and collisional atomic processes including plasma radiation trapping. Relevant atomic cross sections and rates were computed with the FAC code. The calculations were performed at constant particle number density and time-histories of temperature and external radiation flux were selected in order to approximate the experimental conditions at Z. For the same set of time-histories, calculations were done in a full time-dependent mode and also as a sequence of instantaneous, steady states in order to assess transient effects.

This research was sponsored in part by the National Nuclear Security Administration under the High Energy Density Laboratory Plasmas grant program through DOE Grant DE-FG52-09NA29551, and SNL.

Hydrodynamic and X-ray modeling of a supernova remnant expanding in a wind-blown bubble

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Abstract

Kes 27 is a mixed-morphology or thermal composite supernova remnant (SNR), which shows X-ray emission from both an outer shell structure and within the interior. Chandra data from 2003 show two incomplete shell-like features in the northeastern half (Chen et al. 2008, hereafter CSSL08), an outer X-ray arc and an inner harder X-ray region. The morphology was explained by CSSL08 as a SNR expanding within a pre-existing cavity, with a density gradient increasing from west to east. In this poster we will present hydrodynamic simulations aimed at reproducing the X-ray morphology of this remnant, followed by a computation of the X-ray emission, and comparison to observations. In the process, we will also illustrate the general hydrodynamic and X-ray properties of supernova remnants evolving in wind-blown cavities.

Ionization-gasdynamics models and X-ray spectra of wind-blown nebulae around massive stars

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Abstract

Using a new code that employs a self-consistent method for computing the effects of photo-ionization on circumstellar gas dynamics, we model the formation of wind-driven nebulae around massive stars. Our algorithm incorporates a simplified model of the photo-ionization source, computes the fractional ionization of hydrogen due to the photo-ionizing flux and recombination, and determines self-consistently the energy balance due to ionization, photo-heating and radiative cooling, taking into account the effects of geometrical dilution and of column absorption of radiation. Shocks are treated using an artificial viscosity, and grid expansion is available. We take into account changes in stellar properties and in stellar mass-loss over the star's evolutionary lifetime. Our multi-dimensional simulations reveal the presence of strong ionization front instabilities, similar to those seen in galactic ionization fronts.

Using various X-ray emission models, we compute detailed X-ray spectra of wind-blown nebulae from our simulations, as would be seen with the ACIS-S instrument on Chandra. These are compared with observed X-ray spectra. We show that at certain epochs of the evolution, our synthetic spectra in the Wolf-Rayet (W-R) stage agree quite well with those obtained from observed W-R nebulae. Unlike other calculations, our detailed spectra indicate that diffuse X-ray emission from most main sequence and W-R nebulae would NOT be easily observable with currently available X-ray satellites, which is consistent with the observational data.

Radiation magnetohydrodynamic flows in laboratory astrophysics: from similarity properties to experimental simulation

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Abstract

Radiation magnetohydrodynamic flows are ubiquitous in high-energy astrophysics environments. The dynamics of accretion disks, the astrophysical jets emitted by different types of compact objects and the dynamics of accretion processes in magnetic X-ray binary systems are perfect examples. All these phenomena present high-energy regimes in which intense magnetic field, radiation and hydrodynamic are strongly coupled. Some of them present interesting similarity properties which allow to reproduce them in laboratory.

In this work we present the similarity properties of such flows in different radiation regimes (optically thin and optically thick regimes). The associated scaling laws will be established and the link with high-pulsed facilities experiments will be discussed.

RMHD simulations of magnetorotational turbulence in protoplanetary disks

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Abstract

Protoplanetary disks are accretion disks around young, solar-type stars that are supposed to be the birthplace of planets. The accretion dynamics is most likely driven by hydromagnetic turbulence due to the magnetorotational instability (MRI). Since the interior of protoplanetary disks is not directly accessible to observations, numerical simulations play an important role in our quest to understand the physical processes operating inside these objects. When considering the planet-forming region (which is located at a distance of several au from the central star), two major complications arise: (1) The disk gas is mostly optically thick (requiring radiative transfer modelling), and (2) due to insufficient ionization there exists a non-turbulent 'dead zone'. The ionisation level, and therefore the extent of the dead zone, depend on factors like the stellar X-ray luminosity, the temperatures in the disk and the abundance of micron sized dust grains. We present recent results from simulations which take into acount all relevant physical processes, leading to a realistic model of magnetorotationally turbulent protoplanetary disks.

Dynamics of the innermost accretion flows around compact objects: magnetosphere-disk interface, global oscillations and instabilities

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[2]Cornell University

Abstract

We study global non-axisymmetric oscillation modes and instabilities in magnetosphere- disk systems, as expected in neutron star X-ray binaries and possibly also in accreting black hole systems. Our two-dimensional magnetosphere-disk model consists of a Keplerian disk in contact with an uniformly rotating magnetosphere with low plasma density. Two types of global overstable modes exist in such systems, the interface modes and the disk inertial-acoustic modes. We examine various physical effects and parameters that influence the properties of these oscillation modes, particularly their growth rates. The interface modes are driven unstable by Rayleigh-Taylor and Kelvin-Helmholtz in- stabilities, but can be stabilized by the toroidal field (through magnetic tension) and disk differential rotation (through finite vorticity). General relativity increases their growth rates by modifying the disk vorticity outside the magnetosphere boundary. The interface modes may also be affected by wave absorption associated with corotation resonance in the disk. In the presence of a magnetosphere, the inertial-acoustic modes are effectively trapped at the innermost region of the relativistic disk just outside the interface. They are driven unstable by wave absorption at the corotation resonance, but can be stabilized by modest disk magnetic fields. The overstable oscillation modes studied in this paper have characteristic properties that make them possible candidates for the quasi-periodic oscillations observed in Galactic X-ray binaries.

Calibration of computer models for radiative shock experiments

Jean Giorla[1], Emeric Falize[1,4], Clotilde Busschaert[1,4], Berenice Loupias[1], Michel Koenig[2], Alessandra Ravasio[2], Alexandra Dizière[2], Josselin Garnier[3], and Claire Michaut[4]

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Abstract

POLAR experiments aimed to mimic the astrophysical accretion shock formation in laboratory using high-power laser facilities. The dynamics and the main physical properties of the radiative shock produced by the collision of the heated plasma with a solid obstacle have been characterised on recent experiments and compared to radiation hydrodynamic simulations. This poster will present the statistical method based on Bayesian inference used to calibrate the main unknown parameters of the simulation and to quantify the model uncertainty.

Radiation-hydrodynamic simulation of experiments with intense lasers generating collisionless interpenetrating plasmas

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Abstract

Collisionless shocks, shocks generated by plasma wave interactions in regions where the collisional mean-free-path for particles is long compared to the length scale for instabilities that generate magnetic fields, are found ubiquitously in astrophysics. Experiments whose goal is to investigate the production and growth of magnetic fields in collisionless shocks in laboratory-scale systems are being carried out on intense lasers, several of which are measuring the plasma properties and magnetic field generation in counter-streaming, collisionless flows generated by laser ablation. This poster reports radiation-hydrodynamic simulations using the CRASH code to model the ablative flow of plasma generated in order to assess potential designs, as well as infer properties of collected data from previous experiments.

This work is funded by the Predictive Sciences Academic Alliances Program in NNSA-ASC via grant DEFC52- 08NA28616, by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-FG52-09NA29548, and by the National Laser User Facility Program, grant number DE-NA0000850.

Irradiated interfaces in the Carina and Cyg OB2 massive star formation regions

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Abstract

Regions of massive star formation offer some of the best and most easily observed examples of radiation hydrodynamics. The boundary where the fully ionized HII region transitions to the neutral/molecular photodissociationregion is of particular interest because the marked temperature and density contrasts across the boundary lead to evaporative flows and fluid dynamical instabilites that can develop into spectacular pillar-like structures, which when detached from their parent clouds become ionized globules that often harbor a young star at their core. Recent large-scale infrared cameras have made it possible to peer through the dust and observe how these interfaces behave in various emission lines. This poster will summarize the results from two famous regions of massive star formation. The structure in these regions is spectacular and more intricate than more well-studied regions such as the Eagle Nebula and Orion. Observations such as these help motivate the next generation of laboratory experiments of this physical process.

Monte-Carlo simulation of pair and gamma ray production using petawatt lasers

Alexander Henderson[1], Edison Liang[1], Pablo Yepes[1], Xin Wang[1],
Nathan Riley[2], Hui Chen[3], and Scott Wilkes[3]

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[2]University of Texas at Austin, Austin, TX
[3]Lawrence Livermore National Labs, Livermore, CA

Abstract

Irradiating high-Z targets such as gold with ultra-intense lasers produces copious electron-positron pairs and gamma rays. The Bethe-Heitler and brehmstahlung processes dominate production, which makes Monte Carlo simulation of this system particularly attractive. We present results from such a simulation and compare these with results from the Titan laser at Lawrence Livermore National Labs (LLNL) and the Texas Petawatt Laser (TPW) at the University of Texas at Austin.

Parallel computing of radiative transfer in relativistic jets using a Monte Carlo method

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and Shoichi Yamada[2]

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Abstract

We have developed a parallelized multi-dimensional Monte Carlo code for simulating radiative transfer in a relativistic jet from collapsing massive progenitor of long-duration gamma-ray bursts (GRBs). Although a large number of sample photons and long-term tracking in a scattering medium are required for accurate prediction of light curves and emission spectra with less statistical errors, they need huge computational loads. The developed code achieved a high parallel efficiency which helps us to obtain solutions in a practical computational time. We have conducted radiative transfer simulation with hydrodynamical data of the relativistic jet in which Thomson scattering dominates compared to absorption. The obtained light curve and emission spectra depend on the jet structure, and a power-law of the light curve will be discussed in the context of GRBs.

The Eagle Nebula science on NIF experiment

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Abstract

The Eagle Nebula NIF experiment was one of nine selected for laser time through the Science on NIF program. The goal of this scale laboratory experiment is to study the dynamic evolution of distinctive structures in star forming regions of astrophysical molecular clouds such as the Pillars of the Eagle Nebula. That evolution is driven by photoionizing radiation from nearby stars. A critical aspect of the radiation is its very directional nature at the photoionization front. The long duration of the drive and its directionality can generate new classes of instabilities and dynamic flows at the front that may be responsible for the shapes of Pillars and other structures. The experiment will leverage and modify the existing NIF Radiation Transport platform, replacing the target at the back end of the halfraum with a collimating aperture, and extending the existing 20 ns drive to longer times, using a combination of gas fill and other new design features. The apertured, quasi-collimated drive will be used to drive a target placed 2 mm away from the aperture. The astrophysical background and the status of the experimental design will be presented.

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

An experimental concept to measure opacities under solar-relevant conditions

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Abstract

Recent solar abundance models (Asplund 2009) use a significantly lower abundance for C, N, O compared to models used roughly a decade ago. Although the models used now are much more sophisticated than before, a discrepancy still exists between the abundances in the models and the abundances determined by helioseismic inferences. Agreement can be obtained by ad hoc adjustments to the opacity of high-Z (Z > 2) elements ranging from a few percent in the solar interior to as much as 30

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Direct laser-driven quasi-isentropic compression studies of iron relevant for Earth-like planets interiors

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Abstract

The study of iron using quasi-isentropic compression yielding thermodynamical parameters different from those achieved on the principal Hugoniot might allow to access thermodynamic realm relevant for the understanding of the iron solid-liquid phase transition in the interiors of Earth and Earth-like planets (330-1500 GPa, 5000-8000K). However, the iron alpha-epsilon solid-solid phase transition at the pressure of 13 GPa favours shock formation during quasi-isentropic compression. Understanding this shock formation mechanism is crucial for reproducing Earth and Earth-like planets core conditions on laboratories by ramp compression. Here we will present results of direct laser-driven quasi-isentropic compression experiments on iron samples. These experiments were performed on the LULI2000 laser facility and LIL. On one hand, different pressure ramp shapes, corresponding to different loading rates, were used to investigate the alpha-epsilon transition dynamics and on the other hand iron was ramp compressed until 700 GPa. Results will be presented and compared to simulations. The implication of these results for Earth-like planets characterisation will be discussed.

Accelerating piston action and plasma heating in high-energy density laser plasma interactions

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Abstract

The strong light pressure associated with ultraintense short pulse laser beams of $I > 10^{18}$ W/cm^2 is a central component to many high-energy density (HED) applications. In this presentation, a more realistic treatment of the laser 'hole boring' process is developed through analytical modeling and particle-in-cell simulations. Key novel aspects of the dynamics are elucidated for the first time, including a self-consistent treatment of the target-front plasma volumetric heating and expansion. The further inclusion of a realistic laser pulse profile is shown to play an essential role, qualitatively modifying the particle phase space, and attenuating the axial depth of the hole boring channel for many common configurations. In a broad sense, our results show that the ponderomotive hole boring of a realistic laser pulse gives rise to richer particle dynamics, though ultimately represents a less robust 'pressure source' than previously thought. Implications of these results for astrophysically-relevant HED applications, such as the ability to drive collisionless shocks into the overdense target, are highlighted. These considerations are germane to shocks in jets of active galactic nuclei and gamma-ray bursts.

Results of the TPW 2011 experiment on hot electrons and gamma-rays from thick Au targets

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Abstract

We report results from the July 2011 run of the Rice-UT experiments using TPW to irradiate 1 - 3 mm thick Au targets. The TPW energy was around 50 J focussed to peak intensity of a few $\times 10^{19}$ W/cm^2. We measured the spectra of hot electrons out to > 50 MeV using a compact magnetic spectrometer. We find that the hard tail temperatures are consistent with ponderomotive scaling. However, the spectra are truncated at low energies and show much narrower peaks than typcial hot electron spectra. The peak electron energies lie between 9 and 20 MeV. We obtained only upper limits to the positron spectra due to the low laser energy and high background. We also measured the bremsstrahlung spectra and angular distribution of the gamma ray output. These results are consistent with GEANT4 simulations.

Work supported by DOE SC0001481.

Experiments and modeling of photoionized plasmas at the Z facility

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Abstract

Astrophysical environments such as x-ray binaries, active galactic nuclei, and accretion disks of compact objects contain photoionized plasmas. Developments in pulsed power sciences like those at the Z pulsed-power facility facility at Sandia National Laboratories have led to the availability of a powerful x-ray source that enables us to produce and study in the laboratory photoionized plasmas relevant for astrophysics under well characterized conditions. We discuss an experimental and modeling effort in which the intense x-ray flux emitted at the collapse of a z-pinch experiment conducted at Z is employed to produce a neon photoionized plasma. The broadband radiation flux from the z-pinch is used to both drive the photoionized plasma and provide a source of backlighting photons to study the atomic kinetics through K-shell line absorption spectroscopy. The design of the experiment involves view factor calculations to model the radiation flux driving the plasma, and radiation hydrodynamic simulations to evaluate the overall dynamics and uniformity of the plasma. The plasma is contained in a cm-scale gas cell located at several distances from the z-pinch, and the filling pressure is carefully monitored in situ all the way to shot time since it determines the particle number density of the plasma. Time-integrated and gated transmission spectra are recorded with a TREX spectrometer equipped with two elliptically-bent KAP crystals and a set of slits to record up to six spatially-resolved spectra per crystal in the same shot. The transmission data shows line absorption transitions in several ionization stages of neon including Be-, Li-, He- and H-like Ne ions. Detailed modeling calculations of the absorption spectra are used to interpret and perform the analysis of the transmission spectra with the goal of extracting the charge state distribution and the atomic population kinetics of the photoionised plasma. The data analysis is performed with the aid of a novel application of genetic algorithms to plasma spectroscopy. Plans for producing photoionized plasmas of other elements and mixtures are discussed as well.

This research was sponsored in part by the National Nuclear Security Administration under the High Energy Density Laboratory Plasmas grant program through DOE Grant DE-FG52-09NA29551, and SNL.

Laser produced plasma XUV opacity measurement at LULI 2000 facility for stellar pulsation studies

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Abstract

Recent laser-produced plasma opacity measurement has been performed at the LULI 2000 facility coupling ns and ps multi 100J beams. Transition 3d elements, among Fe, Ni, Cu and Cr were probed in the XUV 50-250 eV photon energy range. Those elements are eminently known to be responsible for the k-mechanism at the origin of pulsations for massive stars such as beta-Cepheids. Relevant plasma conditions show noticeable discrepancies between OP and OPAL opacity data used in the astrophysical community [1]. Similarly extended comparisons at laboratory conditions show a relatively large dispersion in principle accessible to the measurement [2]. Principle, improvements of recent experiments and preliminary results will be presented.

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[2] D. Gilles et al., 2011, HEDP 7, 312

Areal density measurement from a photoionized Neon plasma using the Lyman alpha transition

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Abstract

Photoionized plasmas are a special class of plasmas that occur frequently in astrophysical phenomenon. Though difficult to create on Earth, experiments on the Z-Machine at Sandia National Labs have begun to explore these plasmas in an effort to study the atomic kinetics involved and to provide data to be used to benchmark spectral synthesis models for photoionized plasmas. The focus of this work was to obtain areal density measurements from time-resolved absorption spectra of a Neon photoionized plasma by utilizing the Lyman alpha transition in absorption. The areal-density is based on H-like Neon ions in the initial state of the transition, i.e. the ground state. In order to do this, a suite of IDL programs were developed to reduce the data, extract transmission spectra, and calculate synthetic data. With these tools, several sets of shot data from Z experiments were studied. Sensitivities in the areal density measurement with respect to our processing and analysis procedures as well as comparisons with time-dependent collisional-radiative atomic kinetics calculations were also investigated.

This research was sponsored in part by the National Nuclear Security Administration under the High Energy Density Laboratory Plasmas grant program through DOE Grant DE-FG52-09NA29551, and SNL.

Self-generation of magnetic fields in discontinuous plasmas

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Abstract

Hydrodynamic instabilities play an important role in the evolution of astrophysical systems. The Rayleigh-Taylor instability (RTI), for example, occurs when a dense fluid is accelerated against a light fluid, producing well known finger-like structures and material mixing. In the case of supernova (SN) explosions, RTI occurs when a blast wave moves through materials of varying densities, such as layers of hydrogen and helium. Scientists have attempted to investigate this system experimentally in a laboratory setting. In our supernova Rayleigh-Taylor mixing experiment on the Omega laser (Kuranz et al. 2010) we accomplished this by using a laser to irradiate a target and drive a blast wave through material which has been designed to mimic the H/He interface in a core-collapse supernova progenitor envelope. The experimental results differed from simulation outcomes, most notably by revealing suppressed RT mushroom-cap formation and significantly more extended RT spikes.

In this computational study, we consider the effects of magnetic fields and thermal conductivity on RTI. It is known that a misalignment of temperature and electron density gradients can generate a magnetic field from zero-field initial conditions (the Biermann Battery effect). This field can then be modified due to complex interactions between ions and electrons in the plasma. Magnetic field and thermal conductivity are known to modify RTI growth and thus may account for the observed differences between computer models and experimental results. To this end, we implemented and verified generalized Ohm's law and anisotropic thermal conduction using the Braginskii formulation in the FLASH-based Proteus code. We present verification results of our implementation and preliminary results in application to the RTI problem under high-energy density conditions.

Super-luminous supernovae and shock breakout in dense circumstellar medium

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Abstract

Recent supernova observations revealed the existence of super-luminous supernovae which are more than 10 times brighter than other kinds of supernovae. Most of super-luminous supernovae show narrow spectral lines which are interpreted as the emission lines from the dense circumstellar medium surrounding the supernova ejecta. Thus, the interaction between the dense circumstellar medium and the supernova ejecta is thought to be the cause of the high luminosity. Here, we show our numerical LC modeling of super-luminous supernova 2006gy by using a radiation hydrodynamics code STELLA. We show that, in the LC models which can explain the LC of SN 2006gy, the circumstellar medium is so dense that a radiation dominated shock wave appears in the dense circumstellar medium and it breaks out when the shock wave has reached the optically thin region of the circumstellar medium. After the breakout, the precursor appears in the circumstellar medium which makes the photosphere ahead of the shock and makes the supernova very bright.

Laboratory study of cosmically-relevant collisionless shocks via the head-on collision of two high velocity plasma jets

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Abstract

We describe a recently initiated laboratory experiment to form and study cosmically-relevant collisionless shocks via the head-on collision of two high velocity (100-150 km/s) hydrogen plasma jets (initial $n_i \sim 10^{16}$ cm^{-3}, $T_e \sim T_i \sim 5$ eV) launched by pulsed power driven plasma railguns. The experiments will be conducted on the Plasma Liner Experiment (PLX) located at LANL. Although collisionless shocks in plasmas were first predicted in the 1950's and discovered in the 1960's, many research questions relating to the microscopic physics of collisionless shock formation, evolution, and shock acceleration of particles to very high energies remain unanswered. The proposed experiments will emphasize the ability to (1) control and scan physics parameters over a range of values and across physics regimes in order to validate physics models, and (2) obtain far more measurements in both space and time compared to either in situ space satellite measurements or astronomical observations. A magnetic field will be applied via coils at the jet interaction region to access magnetized regimes which are essential for cosmic relevance. In contrast to other much smaller collisionless shock experiments, scale sizes of the jet diameter and shock thickness in our experiments will be $\sim$ 30-50 cm and $\sim$ 1 cm, respectively, enabling detailed characterization of shock structure and evolution via relatively simple diagnostics. Key dimensionless parameters in the experiments will satisfy quantitative physics criteria for the collisionless shocks to be of cosmic relevance. The objectives of this work are to develop insights into collisionless shocks not obtainable via satellite measurements or astronomical observations alone, and to unfold the specific physics mechanisms underlying collisionless shock formation and shock-particle interactions.

A comparison study of discrete-ordinates and flux-limited-diffusion methods for modeling radiation transport

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Abstract

The Center for Radiative Shock Hydrodynamics (CRASH) seeks to improve the predictive capability for models of Omega laser experiments of radiative shock waves. The laser is used to shock, ionize, and accelerate a beryllium plate into a xenon-filled shock tube. These shocks, when driven above a threshold velocity of about 60 km/s, become strongly radiative and convert most of the incoming energy flux into radiation.

Radiative shocks have properties that are significantly different from purely hydrodynamic shocks and, in modeling this phenomenon numerically, it is important to compute radiative effects accurately. In this presentation, we examine approaches to modeling radiation transport by comparing two methods: (i) a computationally efficient approximation (multigroup flux-limited diffusion), currently in use in the CRASH code, with (ii) a more accurate discrete-ordinates treatment that is offered by the code PDT. We present a selection of updated results from a suite of comparison tests, showing both idealized problems and those that are representative of conditions found in the CRASH experiment.

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Toward an accurate numerical simulation of radiation hydrodynamics in laser ablation plasmas

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Abstract

Laser ablation plasmas are widely used in not only practical applications such as short-wavelength optical source but also realizing high-speed rarefied flow relevant to laboratory astrophysics. However, some assumptions in conventional techniques of radiation hydrodynamics simulation sometimes break in a low-density plasma because of anisotropic radiation filed and non-continuum flow. A non-locally defined variable Eddington tensor can reconstruct the anisotropic field even in flux-limited diffusion approach with reasonable computational loads. We have developed an efficient method of estimating the variable Eddington tensor using Monte-Carlo photon tracking. Simulation results suggest that emission from laser ablation plasma tends to be anisotropic and affects on the structure of the ablation front. Moreover, we will discuss a precise prediction of free-expanding plasma flow, which is expected to produce a collisionless shock wave in laboratory, by coupling with Direct Simulation Monte Carlo (DSMC) technique.

Effects of radiative losses on jet propagation and interaction with an ambient medium

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Abstract

In astrophysics, supersonic collimated outflows from gravitating sources are a common occurrence. Despite large amounts of data collected from observing these objects there are still many open questions on both jet launching and propagation. The jet structure has been the subject of several simulations, observations and theories and is thought to be best described as a multicomponent structure, composed of a dense central region surrounded by a thin cocoon, therefore being highly complex.

In this context, the possibility to simulate the jet formation using high power lasers bears large potential. A number of previous experiments have proven successful in developing optimized target geometries for creating jets and investigating various stages of their evolution.

In earlier work we focused on testing the jet propagation in an ambient medium. Here we present recent studies dedicated to the investigation of collimating effects. We will consider different processes presumed to play a role in the collimation mechanism. In particular we will discuss the consequences of radiative losses in the jet evolution both with and without ambient medium and the influence of inhomogeneous environments, such as surrounding outflows of different density and composition and quasi-stationary gas flows. Using an ensemble of optical and X-ray diagnostics we can access both the thin outer part of the jet and the denser core, thus achieving an extensive measurement of the jet characteristics.

HYDRA simulations of recent collisionless shock experiments performed on OMEGA

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Abstract

Many types of shocks which occur in astrophysical situations are said to be âcollisionlessâ since the thickness of the shock is much smaller than the Coulomb collision mean free path. Self-generated magnetic fields that are present within these collisionless shocks are thought to play a role in several different astrophysical phenomena, such as particle acceleration, and the structuring of supernova remnants. The development and evolution of these self-generated magnetic fields is not entirely understood.

To investigate the microphysics which plays a role in collisionless shock formation in the laboratory, experiments were performed on the Omega laser, whereby two opposing targets are each irradiated with 1016 W/cm2 to produce counter-streaming flows. In experiment, several different target materials were employed to investigate species effects, namely carbon, polyethylene, and beryllium.

To model results obtained in experiment a hybrid PIC code will be employed to capture the effect of the ion kinetics, while treating the electrons with a fluid description. As an initial step to this task, as presented in this work, the behavior of a single flow of laser-produced plasma will be modeled using the Arbitrary Lagrange-Eulerian (ALE) radiation hydrodynamics code HYDRA (Marinak 2001), developed at LLNL.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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Towards a laboratory analog of molecular pillars

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Abstract

Molecular pillars at the edge of HII regions, such as those of the Eagle and Pelican nebulae, are some of the most beautiful objects in the sky. The physics behind such pillars is determined by intense UV radiation from nearby bright young stars. The radiation causes different physical processes to come into play: hydrodynamic instability, photoionization, ablation, recombination, molecular heating and cooling. This diverse environment is amenable to coordinated study with observations, theory and modelling, and HEDLA.

We have obtained new mm-wavelength spectral line observations with the Combined Array for Research in Millimeter-wave Astronomy (CARMA) to look at the underlying structure of dense gas in these objects. Using well-established structure-finding algorithms, we examine the mass, size, density, and velocity distributions of dense clumps in the pillars. These results can be compared to simulations of photoionized pillars which capture expected morphology at various stages of evolution. The understanding of resultant dense gas distribution is crucial for designing a proper NIF target to be used in a well-scaled HEDLA experiment.

Kelvin-Helmholtz instability modeling using the CRASH code

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Abstract

The Center for Radiative Shock Hydrodynamics (CRASH) at the University of Michigan has developed an AMR, Eulerian radiation-hydrodynamics code, CRASH, which can model laser-driven experiments. One of these experiments we performed previously on the OMEGA Laser at LLE was designed to produce and observe the Kelvin-Helmholtz instability. The target design included low-density CRF foam layered on top of polyamide-imide plastic, with a sinusoidal perturbation on the interface and with the assembled materials encased in beryllium. The results of a series of CRASH simulations of these Kelvin-Helmholtz instability experiments are presented. These results will be compared to the experimental observations.

This work is funded by the Predictive Sciences Academic Alliances Program in NNSA-ASC via grant DEFC52-08NA28616, by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-FG52-09NA29548, and by the National Laser User Facility Program, grand number DE-NA0000850.

Intra-jet hydrodynamics in two weakly collisional counterstreaming jets

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Abstract

Counterstreaming laser-generated plasma jets can serve as a test-bed for the studies of a variety of astrophysical phenomena, including collisionless shock waves. In the latter problem, the jetâs parameters have to be chosen in such a way as to make the collisions between the particles of one jet with the particles of the other jet very rare. This can be achieved by making the jet velocities high and the Coulomb cross-sections correspondingly low. On the other hand, the intra-jet collisions for high-Mach-number jets can still be very frequent, as they are determined by the much lower thermal velocities of the particles of each jet. This paper describes some peculiar properties of intra-jet hydrodynamics in such a setting: the steepening of smooth perturbations and shock formation affected by the presence of the "stiff" opposite flow; the stretching of the shock fronts by the shear flow; the shear-flow enhancement of the seed magnetic field created by the "Biermann battery" effect. Potential applications to astrophysical colliding plasmas are discussed.

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Decelerated blast waves and self-similar radiative cooling in supernova remnants

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Abstract

Radiative blast waves (BW) in supernova remnants (SNR) remain a difficult subject nowadays. The SNR expansion is usually decomposed in three stages [1, 2]. First the ballistic phase where the radius, R(t), of the SNR is proportional to the time [3], second the Sedov-Taylor regime [4] described by a well understood self-similar expansion, $R(t) = t^{\frac{2}{5}}$ (in spherical geometry), and third a radiative stage with $R(t) = t^q$, and $1/4<q<2/5$, where the radiative cooling of the expanding flow produces the formation of a thin dense cold shell until thermal energy of all the swept gas is rapidly radiated and as consequence the thin shell enters in a Momentum-Conserving (MC) phase, with $R(t) = t^{\frac{1}{4}}$ [1,2]. In this former stage the internal pressure of the shell produces its expansion and the end of BW.

One of the main difficulty describing theoretically and self-consistently BW is that adiabatic shocked shell self-similar solutions do not exists for $q<2/5$ [5]. Hence in order to take into account, phenomenologically, the cooling rate, the ratio of specific heats for the gas behind the shock, has been chosen in the literature close to unity [6]. However, following this approach, even for the very small and unrealistic values of the ratio of specific heats, the growth rate of instability is much weaker than the Rayleigh-Taylor growth rate and hence cannot explain in our opinion the instability and fragmentation observed in SNR.

In order to cover this lack of self-similar solutions in the third stage of SNR expansions we have relaxed the adiabatic assumption by including a cooling function A, only depending on time, $A = t^r$. The rigorous 1D self-similar solution is derived provided the exponent satisfy $r=2q-3$ where the expansion rate, q, can be less than 2/5. The solution is governed by a dimensionless cooling parameter $Ac=Kp\times v0\times t0/Bo$. Here Bo is the Boltzmann number of the flow, Kp is a mean volume Planck opacity, and v0 and t0 are the characteristic velocity and the hydrodynamic time, respectively, of the BW. Two main results arise. First, even with energy losses, the dynamics with $q=2/5$ (Sedov exponent) still exists and, second, for Ac larger than unity the profile of density decreases with radial coordinate, in contrast to the adiabatic case, and the growth rate of the instability becomes much larger than the one derived by Ryu and Vishniac [6].

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Nonlinear evolution of a thin material layer with accretion

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Abstract

In the radiative stage [1] of blast waves (BW) in supernova remnants (SNR), the radiative cooling of the expanding flow produces the formation of a very thin and very dense cold shell accreting the material of the cold interstellar medium. Disposing of a self-consistent nonlinear equations system for an infinitely thin layer accreting material becomes very relevant in order to study the nonlinear evolution of those wavelength perturbations which are much larger than the thickness of the layer. Nonlinear Rayleigh-Taylor evolution of thin layers, without accretion, has been considered in the past [2]. In this work we have extending such study including accretion and more general ambient conditions. Linear and nonlinear evolution are studied and in particular they are compared with the linear approximation equations derived by Vishniac [3].

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Laboratory astrophysics research at HZDR

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Abstract

The "Helmholtz-Zentrum Dresden-Rossendorf" (HZDR) research center covers a wide area of fundamental research in the fields of matter, health and energy. In particular for the first domain, a key topic is the behavior of matter in strong fields. The center operates several large-scale facilities of excellent research: The "Dresden High Magnetic Field Laboratory" (HLD), the accelerator and radiation source ELBE and the high-intensity laser system DRACO.

In view of preparatory research and training for the upcoming x-ray free electron laser XFEL at Hamburg, an initiative was taken in order to combine the expertises of generating ultra-strong magnetic fields, high-power laser-matter interaction, plasma physics, radiation physics and material science. The junction of all of these fields settles exactly at laboratory astrophysics.

We will present our experiences in the individual fields, outline the project and discuss possible experiments.

FLASH hydrodynamic simulations of experiments to explore the generation of cosmological magnetic fields

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Abstract

We report the results of FLASH hydrodynamic simulations of the experiments conducted by the University of Oxford High Energy Density Laboratory Astrophysics group and its collaborators at the Laboratoire pour lâUtilisation de Lasers Intenses (LULI). In these experiments, a long-pulse laser illuminates a target in a chamber filled with Argon gas, producing shock waves that generate magnetic fields via the Biermann battery mechanism. We first present the results of verification tests of FLASH 2D cylindrical hydrodynamic simulations of the LULI experiments. We then describe the results of a series of simulations using FLASH that explore the sensitivity of the properties of the shocks to the laser energy and the density of the gas.

Development of a polarization resolved spectroscopic diagnostic for measurements of the magnetic field in the Caltech coaxial magnetized plasma jet experiment

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Abstract

In the Caltech coaxial magnetized plasma jet experiment, fundamental studies are carried out relevant to spheromak formation, astrophysical jet formation/propagation, solar coronal physics, and the general behavior of twisted magnetic flux tubes that intercept a boundary. A non-perturbing visible spectroscopic method has been implemented to observe the Zeeman splitting in the emission spectra in order to measure the magnetic field spatial profile. We designed and constructed a polarization-resolving optical system that can simultaneously detect left- and right-circularly polarized emission with both high throughput and small extinction ratio. By applying this system to NII spectra, the spatially resolved magnetic field magnitude was determined using an inversion method.

Radiatively cooled shocks in colliding supersonic plasma flows using inverse wire array Z-pinches

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Abstract

Radiatively cooled shocks have applicability to a range of observations, from the interaction of young star jets with interstellar media, to solar winds and accretion phenomena. These systems combine the physics of radiation and hydrodynamics in a non-trivial manner, and are therefore of great interest to simulate.

Experiments published in [1] show that the ablation-phase of a wire array z-pinch can be used as a test-bed for radiative bow shocks. In this paper we will present experiments on the MAGPIE facility designed to use the diverging ablation plasma flow of an inverse (exploding) array set-up [2], which significantly increases diagnostic access to measure parameters of the shocks. This flow can interact with obstacles of different geometries to study features of the bow shocks and reverse shocks created. Interaction of the plasma streams from individual wires allows formation of oblique shocks and their incidence angles can be controlled by positioning of the wires.

The rate of radiative cooling in shocks will be controlled by selection of the wire material. The set-up also allows study of differing regimes of flow collisionality and the possibility to vary magnetic fields in the interaction region to allow magnetically dominated interactions.

Spatially and temporally resolved plasma densities will be measured using laser interferometry. Measurements of flow velocities and temperatures across shock fronts will be obtained using optical Thomson-scattering. Results of the first experiments with this set-up will be presented.

[1] D. J. Ampleford et al., Phys. Plasmas 17, 056315 (2010)

[2] A. J. Harvey-Thompson et al., Phys. Plasmas 16, 0220701 (2009)

Simulations of reverse radiative shock experiments on the Omega Laser

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Abstract

A new experimental platform aimed at producing reverse radiative shocks relevant to Cataclysmic Variables (CV) has recently been carried out on the Omega-60 facility. CRASH simulations are used as an additional source of data and for comparison to experiment. In the experimental target, a tin plasma ejecta propagates in vacuum down an acrylic tube and produces a reverse, radiative shock in the flow when impeded by a fixed aluminum wall. Simulations suggest behavior that is consistent with experiment. Shock compression values and ion temperatures are physical quantities that can be compared between simulation and experiment. The goal of the experiment and simulations is to probe the optical and morphological properties of reverse shocks found in CV systems.

Simulations of radiative effects on Rayleigh-Taylor using CRASH

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Abstract

Future experiments at NIF will be able to create conditions relevant to Rayleigh-Taylor instabilities in a radiatively shocked environment, such as in a supernova. In preparation for these experiments we are using the CRASH code to explore the behavior of these instabilities. Previous simulations of high-energy-density Rayleigh-Taylor instabilities in the presence of a radiative shock demonstrate a different behavior when compared to non-radiative cases.

FLASH magnetohydrodynamic simulations exploring the amplification by turbulence of magnetic fields

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Abstract

We report the results of benchmark FLASH magnetohydrodynamic (MHD) simulations of experiments conducted by the University of Oxford High Energy Density Laboratory Astrophysics group and its collaborators at the Laboratoire pour lâUtilisation de Lasers Intenses (LULI). In these experiments, a long-pulse laser illuminates a target in a chamber filled with Argon gas, producing shock waves that generate magnetic fields via the Biermann battery mechanism. We first present the results of verification tests of the implementation of 2D cylindrical geometry in the unsplit MHD solver in FLASH. We then describe the results of benchmark 2D cylindrical MHD simulations of the LULI experiments using FLASH that explore the possibility of magnetic field amplification by turbulence that is associated with the shock waves and that is induced by a grid placed in the gas-filled chamber.

Monoenergetic ion bunch generation by laser and double layer thin foil target interactions

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Abstract

We present a novel scheme to generate monoenergetic ion bunches based on high power laser facilities, such as Texas PetaWatt Laser Facility (TPW). We investigate high energy ion bunch generation from double layer thin foil target irradiated by intense linearly polarized (LP) laser pulse using two-dimensional (2D) particle-in-cell (PIC) simulations. With counting in the effect of pre-pulse, we make the target with two different kinds of materials, low Z in the front and high Z in the rear. The low-Z ions are accelerated by the laser-driven hot electrons and penetrate through the high-Z ion layer to generate a quasi-monoenergetic ion bunch, and this bunch will continue to be accelerated by the quasi-stable electrostatic sheath field, which is formed by the immobile high-Z ions and the hot electrons, with lower instability. With truncating the long pre-pulse, the high quality monoenergetic ion bunch is gained. This mechanism offers possibility to generate monoenergetic ion bunch without ultrahigh-contrast and ultrahigh gradient laser pulses in beam generation experiments, which is confirmed by our simulations.

Supported by DOE grant DE-SC-000-1481.

Improvements to the high energy density physics capabilities in FLASH

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Abstract

FLASH is a modular and extensible compressible spatially adaptive radiation-hydrodynamics code that incorporates capabilities for a broad range of physical processes, performs well on a wide range of existing advanced computer architectures, and has a broad user base. We have been adding capabilities to FLASH to make it an open science code for the academic HEDP community.

We summarize the improvements we have made to the HEDP capabilities of FLASH during the past 18 months. Several variants of Eulerian Hydro and MHD solvers are now available for advancing 1-T (one temperature), 2-T (distinct ion+electron), and 3-T (ion+electron+radiation temperature) problems in multiple geometries. A semi-implicit multigroup flux-limited diffusion solver has been implemented. The EOS unit has been enhanced with multitemperature multitype capabilities; EOS and opacities can now combine tabular and analytic models for different materials. Numerous improvements have been made to the ray tracing implementation used for modeling energy deposition. FLASH now can handle arbitrarily shaped rigid bodies in the Hydro/MHD flow. Results of several verification tests involving radiative and non-radiative shocks will be presented.

This work was supported in part at U. Chicago by ASC, National Nuclear Security Administration, DOE.

A new way to generate collimated plasma jets?

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Abstract

We may have a new way to generate collimated, high-Mach-number plasma jets for laboratory astrophysics experiments. Analytic calculations show that irradiating the rear side of a cone-shaped foil can produce a collimated plasma jet with a Mach number of more than 2. Preliminary numeric simulations confirm this. We intend to test this method with a day of experiments at OMEGA (Laboratory for Laser Energetics, Rochester, New York) in April 2012.

If successful, this will be the first step in an experimental campaign to investigate the affects of magnetic fields on mixing plasma jets. We hope to create a swirling disk of magnetized plasmaâand possibly witness the turbulent dynamoâby firing roughly half a dozen such jets towards each other. However, for such an experiment to succeed, the disk must rotate more quickly than it expands, requiring the contributing jets to have $M > 2$.

This work is funded by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-FG52-09NA29548, and by the National Laser User Facility Program, grant number DE-NA0000850.

Experimental results on seed magnetic fields generation in laser produced shock waves

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Abstract

Even if astronomical observations indicate that large scale magnetic fields are ubiquitous in the universe, their origin and amplification mechanisms remain one of the most intriguing mystery of modern astrophysics.

We have experimentally studied the generation and amplification of self-generated magnetic fields at shock fronts using a high power laser. This approach is based on the scaling of astrophysical environments to laboratory dimensions, yet preserving the essential physics.

In this experiment, performed at the Laboratoire pour l'Utilisation des Lasers Intenses (LULI2000) laser facility, a nanosecond laser pulse was focused on a carbon rod inside a low pressure gas filled chamber, generating an asymmetric blast wave. Three-axis induction coils placed several centimetres from the target were used to measure the generated magnetic fields, while several optical diagnostics, including interferometry, Thomson scattering, Schlieren and space resolved emission spectroscopy, were set up to measure the shock wave properties. Here we will present the results and discuss the B-field generation by the Biermann battery mechanism [G. Gregori, Nature, v. 481, p. 480, 2012]. The scaling to the protogalactic shocks will also be considered.

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