Thursday, May 08, 2014

Book of abstracts

HEDLA 2014

10th International Conference on High Energy Density Laboratory Astrophysics

May 11 – 16, 2014
Bordeaux, France

LOCAL ORGANIZING COMMITTEE (LOC)

Serge Bouquet (chair, CEA), Andrea Ciardi (Paris Observatory), Brigitte Flouret (CEA), Emmanuelle Lesage (CELIA Bordeaux), Dominique Maillet (CEA), Claire Michaut (co-chair, Paris Observatory), Denis Penninckx (CEA), Xavier Ribeyre (CELIA Bordeaux), and Valentine Wakelam (Laboratory of Astrophysics Bordeaux)

SCIENTIFIC ORGANIZING COMMITTEE (SOC)

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PROGRAM

TOPICS

• **Plasma physics** (collisionless shocks, ultra-strong fields, turbulence, instabilities)

• **Stellar explosions** (exploding systems, novae, white dwarfs, neutron stars, SNe, SNRs, GRBs, XRBs, XRFs)

• **Magnetized high-energy density laboratory astrophysics** (MHD flows, reconnection, magnetised shocks, dynamo)

• **Astrophysical disks, jets, and outflows** (stellar/AGN jets, accretion, high Mach number flows)

• **Stellar astrophysics** (solar physics, nucleosynthesis, opacities)

• **Computations in high-energy density physics** (astrophysical simulations, design of experiments, validation studies)

• **Radiative Hydrodynamics** (radiative shocks, radiatively driven instabilities, molecular clouds, stellar winds, photoionisation, dust)

• **Warm dense matter** (planetary interiors, high-pressure EOS, dense plasma atomic physics)

Monday, May 12, 2014

8:45-9:00	Information
Session 1: Stellar explosions, chair: Serge Bouquet	
9:00-9:30	**Shigehiro NAGATAKI** (invited speaker) page 33 Supernova Explosions: From Engine to Remnant
9:30-9:50	**Yonatan ELBAZ** page 47 Studying the evolution of hydrodynamic instabilities using high power lasers
9:50-10:05	**Tomasz PLEWA** page 71 Core-Collapse Supernova Explosions and Experiments on the National Ignition Facility
10:05-10:20	**Oliver PIKE** page 72 Observing two-photon pair production for the first time in the laboratory
10:30-11:00	*Coffee break*
Session 2: Stellar astrophysics, chair: Claire Michaut	
11:00-11:30	**Daniel CASEY** (invited speaker) page 17 Opening new opportunities in nuclear astrophysics with plasma nuclear science
11:30-11:50	**Manoel COUDER** (invited speaker) page 20 Nuclear astrophysics studies with charged particles in hot plasma environments
11:50-12:05	**Guillaume LOISEL** page 48 Progress and status of ZAPP: The Z astrophysical plasma properties collaboration
12:05-12:20	**Uddhab CHAULAGAIN** page 74 Laser experiments on Radiative Shocks relevant to Stellar Accretion
12:30-14:00	***Lunch***
14:00-15:30	**Posters 1**
15:30-16:00	*Coffee break*
Session 3: Computations, chair: Tomek Plewa	
16:00-16:30	**Samuel FALLE** (invited speaker) page 21 Computational Astrophysical Fluid Dynamics
16:30-16:50	**Ricardo FONSECA** (invited speaker) page 22 Particle-in-cell methods in application to modeling astrophysical and HED plasmas
16:50-17:05	**HideakI TAKABE** page 64 Modeling high-energy astrophysics phenomena with ultra-intense lasers
17:05-17:20	**Petros TZEFERACOS** page 49 FLASH magnetohydrodynamic simulations of experiments that study shockgenerated magnetic fields

Tuesday, May 13, 2014

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Session 4: Magnetized HEDLA, chair: Adam Frank	
9:00-9:30	**Jiayong ZHONG** (invited speaker) page 44 The study of magnetic reconnection with Shenguang II lasers
9:30-9:50	**Lee SUTTLE** (invited speaker) page 40 Structure of reverse shocks formed in the collision of a supersonic, magnetized plasma flow with a planar obstacle
9:50-10:05	**Hye-Sook PARK** page 76 Astrophysically relevant electromagnetic plasma instabilities in high-power laser generated counter-streaming plasma flows
10:05-10:20	**Matthew BENNETT** page 50 Formation of Radiatively Cooled, Differentially Rotating, Plasma Disks in Z-pinch Experiments
10:30-11:00	*Coffee break*
Session 5: Plasma physics, chair: Sergey Lebedev	
11:00-11:30	**Pisin CHEN** (invited speaker) page 18 Laser cosmology
11:30-11:50	**Carolyn KURANZ** (invited speaker) page 30 Radiative shocks in the high-energy-density physics regime
11:50-12:05	**Dongsu RYU** page 68 Diffusive Shock Acceleration at Shock Waves in the Intracluster Medium
12:05-12:20	**Guy MALAMUD** page 58 A two dimensional, singlemode KH experiment on EP
12:30-14:00	***Lunch***
Session 6: Radiative hydrodynamics, chair: Robin Williams	
14:00-14:30	**Howard SCOTT** (invited speaker) page 39 Non-LTE Effects in Radiation-Hydrodynamics Simulations
14:30-14:50	**Matthias GONZALEZ** (invited speaker) page 23 Radiative shocks
14:50-15:05	**Adam FRANK** page 66 Shock-Cloud Interactions and Triggered Star Formation
15:05-15:20	**Javier SANZ** page 63 New results on the Sedov–Taylor point explosion linear stability: application to Ryu–Vishniac and Vishniac instabilities
15:30-16:00	*Coffee break*
Session 7: Warm dense matter, chair: Michel Koenig	
16:00-16:30	**Alessandra BENUZZI-MOUNAIX** (invited speaker) page 15 Investigation of SiO2 in the regime of the Warm Dense Matter : applications to the planetology
16:30-16:50	**Richard KRAUS** (invited speaker) page 29 Shock Thermodynamics of Iron and Impact Vaporization of Planetesimal Cores
16:50-17:05	**Bruce REMINGTON** page 78 New regimes of solid-state plastic flow at extreme conditions for laboratory astrophysics

Wednesday, May 14, 2014

8:45-9:00	Information
Session 8: Computations, chair: Andrea Ciardi	
9:00-9:30	**William RIDER** (invited speaker) page 38 What you do and do not get from V&V
9:30-9:50	**Bart Van der HOLST** (invited speaker) page 28 Radiation hydrodynamics methods and simulations of high-energy-density plasmas
9:50-10:05	**Feilu WANG** page 77 Particle simulation of photoionization by high power laser
10:05-10:20	**Frederico FIUZA** page 52 One-to-one PIC modeling of laboratory studies of collisionless shocks
10:30-11:00	*Coffee break*
Session 9: Jets and outflows, and LMJ/Petal, chair: Patrick Hartigan	
11:00-11:30	**Sylvie CABRIT** (invited speaker) page 16 Young Stellar Objects (YSO) jets
11:30-11:50	**Andrea CIARDI** (invited speaker) page 19 Astrophysics of Magnetized Jets Generated from Laser-Produced Plasmas
11:50-12:05	**Alessandra RAVASIO** page 53 Inertial collimation mechanisms in nested outflows
12:05-12:20	**Joseph CROSS** page 54 Laboratory Investigation of Accretion Shocks at the Orion Laser Facility
12:20-12:45	**Alexis CASNER** page 79 LMJ/PETAL Laser Facility: overview and status
12:45-14:00	***Lunch***
14:00-18:00	**Laser MégaJoule (LMJ) facility visit and CELIA visit**
19:45-23:00	***Gala Dinner***

Thursday, May 15, 2014

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Session 10: Stellar astrophysics, chair: Xavier Ribeyre	
9:00-9:30	**Aake NORDLUND** (invited speaker) page 34 Star and Planet Formation
9:30-9:50	**Michael MONTGOMERY** (invited speaker) page 32 Progress on the White Dwarf Photosphere Experiment on the Z Machine
9:50-10:05	**Maelle LE PENNEC** page 61 Opacity experiments for stellar physics on LMJ+PETAL
10:05-10:20	**R. Paul DRAKE** page 55 Studies of Shock Waves and Related Phenomena Motivated by Astrophysics
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11:00-12:30	**Posters 2**
12:30-14:00	***Lunch***
Session 11: Jets and outflows, chair: Paul Bellan	
14:00-14:30	**Francisco SUZUKI-VIDAL** (invited speaker) page 41 Magnetised shocks in current-driven counter-streaming plasma jets
14:30-14:50	**Patrick HARTIGAN** (invited speaker) page 26 Exploring Astrophysical Shock Wave Dynamics in the Laboratory
14:50-15:05	**Chikang LI** page 65 Structure and Dynamics of Colliding Plasma Jets
15:05-15:20	**Clotilde BUSSCHAERT** page 67 POLAR Project: laboratory simulation of accretion process onto highly magnetized white dwarf
15:30-16:00	*Coffee break*
Session 12: Warm dense matter, chair: Bruce Remington	
16:00-16:30	**Tristan GUILLOT** (invited speaker) page 25 Probing the interiors of planets inside and outside our solar system: Status & perspectives
16:30-16:50	**Kosuke KUROSAWA** (invited speaker) page 31 The thermodynamic response of silicate minerals after meteoritic impacts: Implications for the evolution of planetary atmospheres
16:50-17:05	**François SOUBIRAN** page 73 Hydrogen-Water Mixtures in Giant Planet Interiors Studied with Ab Initio Simulations
17:05-17:20	**Emmanuel D'HUMIERES** page 56 Energy transfer, stochastic heating and radiation emission in counter-propagating plasmas at sub-relativistic velocities
17:40	*Conference Photo*

Friday, May 16, 2014

8:45-9:00	Information
Session 13: Radiative hydrodynamics, chair: Feilu Wang	
9:00-9:30	**Robin WILLIAMS** (invited speaker) page 42 Interface Physics in Laboratory and Astrophysical Plasmas
9:30-9:50	**Arthur PAK** (invited speaker) page 36 Generation of spherical radiative shock waves from ICF implosions
9:50-10:05	**Alexis CASNER** page 57 Long duration drive hydrodynamics experiments relevant for laboratory astrophysics
10:05-10:20	**Neil VAYTET** page 59 Shock waves and star formation using multigroup radiation hydrodynamics
10:30-11:00	*Coffee break*
Session 14: Stellar explosions, chair: Carolyn Kuranz	
11:00-11:30	**Martin OBERGAULINGER** (invited speaker) page 35 Multidimensional modelling of stellar core collapse and explosion
11:30-11:50	**Andrey ZHIGLO** (invited speaker) page 43 Theory and modeling of thermonuclear supernova flames
11:50-12:05	**Mathieu LOBET** page 69 Ultra-fast thermalization of laser-driven ultra-relativistic plasma flows: towards the generation of collisionless pair shocks in the laboratory
12:05-12:20	**Edison LIANG** page 60 Ultra-intense Pair and Gamma-ray Creation using the Texas Petawatt Laser and Astrophysical Applications
12:30-14:00	***Lunch***
Session 15: Magnetized HEDLA, chair: R. Paul Drake	
14:00-14:30	**Patrick HENNEBELLE** (invited speaker) page 27 On the role of magnetic fields in the ISM and star formation
14:30-14:45	**Philipp KORNEEV** page 75 Collisionless magnetized plasma interaction in the context of astrophysical experiments
14:45-15:00	**Mario J.-E. MANUEL** page 70 Magnetization Effects on Collimated Plasma Jets
15:00-15:30	*Coffee break*
Session 16: Plasma physics, chair: Hideaki Takabe	
15:30-16:00	**Gianluca GREGORI** (invited speaker) page 24 Turbulence and magnetic field generation in the laboratory and astrophysics
16:00-16:20	**Hyeon PARK** (invited speaker) page 37 Magnetic reconnection process in the core of toroidal plasmas
16:20-16:35	**Paul BELLAN** page 62 Fast Magnetic Reconnection From Taking into Account Electron Inertia and Hall Physics
16:35-16:50	**Youichi SAKAWA** page 51 Collisionless shock experiments using large-scale lasers
16:50-17:15	Closing remarks

INVITED TALKS

Investigation of SiO_2 in the regime of the Warm Dense Matter : applications to the planetology

Alessandra BENUZZI-MOUNAIX – Invited speaker
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and
Adrien Denoeud, Tommaso Vinci, Alessandra Ravasio, Erik Brambrink, Michel Koenig, Stephanie Brygoo, F. Dorchies, P.M. Leguay, J. Gaudin, F. Guyot, G. Morard, S. Le Pape, N. Ozaki, O. Henry, D. Raffestin, R. Smith, T. Duffy, J.Wang, S. Mazevet

Oral

With the recent discovery of many exoplanets and super-Earth, modeling the interior of these celestial bodies is becoming a fascinating scientific challenge. In this context, it is crucial to accurately know the equations of state and the physical properties of the constituent materials. Among these, $MgSiO_3$ is of major importance since it can be found in the mantle of earth-like planets or in the inner core of Saturn-like planets. Its behavior, including its dissociation into MgO and SiO_2, at high temperatures and pressures drives different scenarios and modeling [1].
Today, an important effort is dedicated to the developments of new laser compression schemes to reach off-Hugoniot conditions relevant to planetology and novel diagnostics to perform microscopic studies to investigate structural changes and test approximations used in calculations.
In this context, we report here, on two experimental campaigns on SiO_2.
The first one concerns recent measurements performed on the LIL (Ligne d'Intégration Laser) laser facility at CEA-CESTA in Bordeaux where we did used a dedicated ramp-tailored laser pulse (2-10 kJ, 20 ns). Here, we generated a first well-controlled shock followed by a quasi-isentropic compression and we deduced the thermodynamical path (P,T) of the compression, showing that we reached conditions existing inside Neptune and Uranus (pressures up to 8 Mbar and 7000K).
The second one concerns the study of the structural properties of SiO_2 at Mbar pressures using X-ray Absorption Near Edge Spectroscopy (XANES). The results were obtained in two different experimental campaigns on the LULI2000 and TITAN lasers at the Ecole Polytechnique and LLNL respectively. With an approach previously tested on aluminum [2,3], we obtained high quality XANES data at different well-controlled temperature and density conditions. Coupled to ab-initio calculations, the XANES spectra allowed us to put in evidence direct signature of the gap closure with temperature and the complex structure of the liquid with density that follows the coordinance of the solid phases. The previous bonded liquid picture [4] of silica at planetary conditions seems to be too simple.

This work has been supported by the ANR PLANETLAB and the Laser Plasma Institute and Association (ILP & ALP).

REFERENCES

[1] K. Umemoto et al., Science 311, 983 (2006)
[2] A. Lévy et al., Rev. Sci. Instrum. 81, 063107 (2010)
[3] A. Benuzzi-Mounaix et al., Phys. Rev. Lett, 107, 165006 (2011)
[4] D. Hicks et al, Phys. Rev. Lett, 97, 25502 (2006)

Jets and outflows from forming stars: Observational clues to physical models

Sylvie CABRIT – Invited speaker
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Oral

The origin of jets and outflows from young stars, and their role in the physics of star and planet formation and interstellar clouds, remain as key open questions in modern astrophysics. I will present an overview of the current status and recent progress in observations of protostellar jets and outflows, with emphasis on their key points of contact with theory. In particular I will review new observational constraints brought by higher angular resolution and expanded wavelength coverage on their collimation scale, degree of ionization and magnetization, hot (10^6 K) component, time variability, shock structure, and large-scale propagation. I will also point to issues which HEDLA might provide direct insights upon.

Opening new opportunities in nuclear astrophysics with plasma nuclear science

Daniel CASEY – Invited speaker
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Oral

Nuclear astrophysics is predominantly a field of observations and modeling of astrophysical phenomena with experiments that are mainly confined to laboratory accelerators. The newly emerging field of plasma nuclear science, performed at High Energy Density (HED) facilities such as the OMEGA laser and the National Ignition Facility, is opening exciting new opportunities to access conditions much like the interior of stars. For example, inertial confinement fusion (ICF) implosions produce extremely dense and hot plasmas that may provide paths for studying plasma electron screening and other plasma-nuclear effects present in stellar cores but not in accelerator experiments. ICF implosions also have very short and intense fusion burns producing extraordinarily high neutron fluxes that are opportune for studying reactions on short lived and excited states relevant to supernova. However, these experiments also come with challenges not found in accelerators. For example, the complex temporal and spatial evolution of these systems can make absolute cross-section measurements difficult and are, in general, quite challenging to model. This talk will present an overview of some current efforts and future plans in this new and very active field.

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Laser Cosmology

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Oral

Recent years have witnessed tremendous progress in our understanding of the cosmos, which in turn points to even deeper questions to be further addressed. Concurrently the laser technology has undergone dramatic revolutions, providing exciting opportunity for science applications.
History has shown that the symbiosis between direct observations and laboratory investigation is instrumental in the progress of astrophysics. We believe that this remains true in cosmology. Current frontier phenomena related to particle astrophysics and cosmology typically involve one or more of the following conditions:

(1) extremely high energy events;
(2) very high density, high temperature processes;
(3) super strong field environments.

Laboratory experiments using high intensity lasers can calibrate astrophysical observations, investigate underlying dynamics of astrophysical phenomena, and probe fundamental physics in extreme limits.
In this talk we give an overview of the exciting prospect of laser cosmology. In particular, we showcase its unique capability of investigating frontier cosmology issues such as cosmic accelerator and quantum gravity.

Astrophysics of Magnetized Jets Generated from Laser-Produced Plasmas

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Oral

The ejection of powerful jets of matter is ubiquitous in the universe. There is now growing evidence that jets originate as wide-angle winds that are magneto-centrifugally accelerated by a large scale magnetic field anchored in an accretion disk. Theoretically, it is the amplification of this magnetic field by differential rotation that generates highly wound helical field lines which self-collimate the wind into a jet. The essence of self-collimation, and its role on the collimation and stability of jets, has been studied not only through multi-dimensional simulations, but also in experiments using dense, magnetized plasmas . These experiments can in fact produce flows that are well approximated by the Euler MHD equations, and whose invariant properties allow meaningful scaling of laboratory to astrophysical fluid dynamics. Self-collimation however, cannot account for the confinement of the entire outflow. The wind solutions in these radially self-similar models formally extend to infinity, and have difficulties for example, in accounting for the observed jet widths. Furthermore, jets dominated by an azimuthal magnetic field are prone to current and pressure-driven instabilities which may disrupt the flow. Efforts to improve on these models, and understanding the collimation of jets, has lead to studies of truncated disk winds, where the whole outflow structure is confined by the thermal pressure of an external medium. In this context, but somewhat overlooked, are the models where the collimation is due to a poloidal magnetic field anchored in a disk, or present in the external environment. In this talk, I will discuss how the flow from an isotropic wind can be shock-focused into bipolar jets by a purely axial magnetic field. I will present results from astrophysically scaled, laser experiment demonstrating that cm-long jets can be generated from a diverging plasma plume when embedded in 0.2 MG magnetic field. In related numerical studies of astrophysical winds, we find that for mass-ejection rates and magnetic field strengths typical of young stellar winds, the expansion of an isotropic wind in a uniform axial magnetic field generates an elongated, eye-shaped cavity bounded by a shock envelope. At its apices, re-collimating shocks appear at a distance ~ 30 – 100 a.u. from the source, and focus the flow into two oppositely propagating jets. The results provide a new scenario of jet collimation and may naturally explains the puzzling presence of stationary x-ray emission sources observed at the base of a number of stellar jets.

Nuclear astrophysics studies with charged particles in hot plasma environments

Manoel COUDER – Invited speaker
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Oral

With the advent of the next generation of Inertial Confinement Fusion facilities such as the National Ignition Facility, studies of nuclear reactions of astrophysical interest could, for the first time, be performed in the same temperature conditions as the stellar cores in their quiescent burning phase. Those studies range from charged particle reactions in the hydrogen and helium burning phase of the stellar evolution to neutron captures reactions on the path of the s-process.

Beside the possibility to study charged particle reaction rates at stellar temperatures, the effect of the free electron cloud on reactions can be evaluated. Currently, most of the stellar hydrodynamic calculations are performed assuming the Debye-Hückel phenomenological expression for the electron screening. In order to experimentally evaluate the electron screening in plasmas, a comparison between experiments at accelerator facilities and at facilities such as the National Ignition Facility (NIF) is needed.

This talk will address steps towards an experimental nuclear astrophysics program to study low energy charged particle reactions at Inertial Confinement Fusion facilities.

Computational Astrophysical Fluid Dynamics

Samuel FALLE – Invited speaker
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Oral

Computational fluid dynamics, indeed all computation, is easy enough when there are no large or small parameters in the problem, but this is unfortunately rarely the case in astrophysics. Although much can be achieved by the intelligent use of dimensional analysis in order to rescale the problem, this is seldom enough to carry out interesting computations on a uniform grid and there is little prospect that increases in computer power can do much to alleviate this in the near future. It is, however, possible to construct hydrodynamic codes that use a hierarchical grid to achieve high resolution in places where the solution varies rapidly and this, combined with rescaling, enormously extends the range of problems that can be tackled. The power of these methods is illustrated by the applying them to the propagation of detonations in Type Ia supernovae.

Particle-in-cell methods in application to modeling astrophysical and HED plasmas

Ricardo FONSECA – Invited Speaker
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Oral

There are several astrophysical and laboratory scenarios where kinetic effects play an important role. These range from astrophysical shocks and plasma shell collisions to high intensity laser-plasma interactions with applications to fast ignition and particle acceleration. Although computationally intensive, fully relativistic particle-in-cell (PIC) codes such as OSIRIS [1] have established themselves as the tool of choice for modeling many these scenarios. Recent developments extend the validity of the PIC model to other scenarios and allow for efficient large scale kinetic modeling with present day computing resources. I will discuss some of the issues involved in performing these large-scale numerical experiments. I will address the efficient use of state-of-the-art Petascale supercomputing systems required for these simulations. I will also discuss the recent advances in extending the standard particle-in-cell algorithm, that allow for separating the laser / target spatial and temporal scales, allowing for full scale modeling of longer interaction lengths and overcritical laser interaction scenarios, and also to include collisional and quantum effects. Illustrations of these developments will be given for relevant scenarios.

[1] R. A. Fonseca et al., Lect Note Comp Sci, vol. 2331, pp. 342-351, (2002)

Radiative shocks

Matthias GONZALEZ – Invited speaker
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and
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Oral

Radiative shocks are shocks in a gas where the radiative energy and flux coming from the very hot post-shock material are non-negligible in the shock's total energy budget, and are often large enough to heat the material ahead of the shock. In recent years, laboratory experiments have been conducted with very high-energy lasers to drive radiative shocks inside gas chambers. These experiments allow new diagnostics of the properties of radiative shocks and allow for the validation of numerical simulations. Many simulations of radiative shocks, both in the contexts of astrophysics and laboratory experiments, use a grey treatment of radiative transfer coupled to the hydrodynamics. However, the opacities of the gas show large variations as a function of frequency and this needs to be taken into account if one wishes to reproduce the relevant physics.
We have performed radiation hydrodynamics simulations of radiative shocks in Ar using multigroup (frequency dependent) radiative transfer with the HERACLES code. The opacities were taken from the ODALISC database. We show the influence of the number of frequency groups used on the dynamics and morphologies of subcritical and supercritical radiative shocks in Ar gas, and in particular on the extent of the radiative precursor. We find that simulations with even a low number of groups show significant differences compared to single-group (grey) simulations, and that in order to correctly model such shocks, a minimum number of groups is required. Results appear to eventually converge as the number of groups increases above 50. We were also able to resolve in our simulations of supercritical shocks the adaptation zones which connect the cooling layer to the final post-shock state and the precursor.

Turbulence and magnetic field generation in the laboratory and astrophysics

Gianluca GREGORY – Invited speaker
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Oral

X-ray and radio observations of supernova remnants, molecular clouds and other astrophysical objects reveal the presence of strong magnetic fields, often up to 100 times stronger than those in the surrounding interstellar medium. Among many possibilities, turbulence is advocated to explain the amplification of magnetic fields and the observed distribution of the synchrotron emission. Turbulence is also believed to play a role in the large scale distribution of the magnetization in the Universe. In the past decade, with the advent of high power laser system, a new area of research has opened in which, using simple scaling relations, astrophysical environment can be effectively reproduced in the laboratory. Here we report the results of such scaled experiments and show that, in the laboratory, questions related to the generation and amplification of magnetic fields can be directly addressed. We will give specific examples concerning to generation of seed fields by the Biermann battery mechanism, turbulent amplification of magnetic fields driven by a ring of stationary clouds, and turbulence induced by jet-cloud collisions. We will discuss the power spectrum of the magnetic field in the experiment and its relation with the the magnetic Reynolds number. Finally, we will give an overview of possible future applications on large scale laser facilities.

Probing the interiors of planets inside and outside our solar system: Status & perspectives

Tristan GUILLOT – Invited speaker
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Université de Nice-Sophia Antipolis, Observatoire de la Cote d'Azur (OCA), France

Oral

We now have discovered more than a thousand exoplanets in orbit around stars as close as a few to several hundred light years away. These planets, whose masses range from that of our Earth and below up to more than Jupiter's mass (and extending to the brown dwarf range) can be characterized with a variety of methods. Understanding their internal structure and evolution requires however models based on accurate equations of state and generally a global understanding of the behavior of matter at pressures ranging from the atmospheric pressure to 10 TPa and more.

Recent progresses in the field essentially stem from first-principles calculations combined to the analyzes of high-pressure experiments in the proper temperature-pressure regime. These led to the characterization of the molecular-metallic transition of hydrogen, of its solidification curve, as well as to the determination of phase diagrams and critical demixing temperatures for various mixtures (e.g. helium and water in metallic hydrogen). We will discuss how these new calculations affect our understanding of the interior structure and evolution of planets - both in our Solar System and outside - and how this will affect the analysis of the data to be brought back by missions such as Juno (to orbit Jupiter by 2016) and Plato (to be launched in 2024 to discover and characterize exoplanetary systems).

Exploring Astrophysical Shock Wave Dynamics in the Laboratory

Patrick HARTIGAN – Invited speaker
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Oral

Shock waves play a key role in shaping the environment and evolution of a variety of objects in the universe. High-resolution spectra and images of shock waves in stellar jets, supernovae remnants, and molecular clouds all reveal a wealth of information related to the dynamics of these flows, and have uncovered several dynamical phenomena that benefit from a detailed understanding of the physics enabled by controlled laboratory experiments. This talk will highlight some recent efforts to construct laboratory analogs of astrophysical shocks, and will discuss additional opportunities where experiments may assist interpreting the complex and growing body of astrophysical data.

On the role of magnetic fields in the ISM and star formation

Patrick HENNEBELLE – Invited speaker
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F-91191 GIF SUR YVETTE CEDEX - France

Oral

I will review the role that we believe magnetic field has on the different steps of the star formation process in the interstellar medium. At large scale, magnetic field modifies the turbulent properties of the flows and tends to make them more coherent. On smaller scales, magnetic field tends to reduce the gas rotation through magnetic braking. This has deep consequence on the formation of protoplanetary disks on binary systems.

Radiation hydrodynamics methods and simulations of high-energy-density plasmas

Bart Van der HOLST – Invited speaker
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Oral

With the emergence of high-energy-density facilities, it is now more straightforward to produce radiative shock waves in which the radiation transport controls the hydrodynamic evolution. Those experiments have revealed many properties of radiative shock, such as ionizing radiative shock precursors and radiative cooling layers. Some of these experiments used shock tubes and produced secondary shocks by wall ablation for sufficiently fast, radiative shocks. More recently, magnetic fields were shown to be important in laser-produced shock waves. These fields can be generated by the Biermann battery effect. Several numerical simulation codes have been developed that can be used to study these radiation hydrodynamic phenomena: CRASH (Unversity of Michigan), FLASH (University of Chicago), RAGE (LANL), HYDRA (LLNL), among others. In this presentation, we describe some of the recent advances in the numerical radiation hydrodynamic methods and the applications towards high-energy-density plasmas.

Shock Thermodynamics of Iron and Impact Vaporization of Planetesimal Cores

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and
Seth Root, Raymond W. Lemke, Sarah T. Stewart, Stein B. Jacobsen, and Thomas R. Mattsson

Oral

The outcome of planetesimal collisions has important consequences for understanding the end stages of planet formation. In particular, the degree of chemical equilibration between the iron cores of planetesimals and the mantle of the growing Earth strongly affects our understanding of the timing of Earth's core formation. To date, the role of shock-induced vaporization of iron during planet formation has not been assessed, which is the result of iron's poorly constrained thermal equation of state. Here we present a novel experimental technique that we implemented at the Sandia Z machine to determine the entropy on the iron Hugoniot and thereby the shock pressure required to vaporize iron upon decompression. We find that the shock pressure to vaporize iron is 507(+65,-85) GPa, which is significantly lower than the previous theoretical estimate (887 GPa) and readily achieved during the high velocity impacts at the end stages of accretion. Vaporization of planetesimal cores by an impact–generated shock will disperse core material over the surface of the growing Earth, which will enhance chemical equilibration with Earth's mantle. Vaporization also decreases the accretion efficiency of planetesimals onto the Moon relative to Earth, providing an explanation for the compcrust.

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Radiative shocks in the high-energy-density physics regime

Carolyn KURANZ – Invited speaker
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and
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Oral

Radiative-flux dominated radiative shocks, which are in a regime where most of the incoming energy flux is converted into radiation. Radiative shocks occur in some accretion phenomena, supernovae, and stellar shocks, as well as, inertial confinement fusion experiments. The loss of a dynamically significant amount of energy via radiation affects the hydrodynamic structure of these systems. The resulting structure can be studied in a laboratory when a high-powered laser is used to drive a significantly fast, high-Z flow. We have performed experiments on the Omega laser facility that explore these types of shocks driven either by a piston or a high-Z flow.

In the piston case, a laser irradiance of ~10^15 W/cm^2 drives a thin Be disk into Xe gas at 1.1 atm. The gas is shocked and accelerated and can reach velocities of over 130 km/s. At such high velocities the radiative fluxes become significant, which leads to extensive radiative cooling. The cooling of the shocked material causes compressions of about 20, which are higher than the typical hydrodynamic shock. In the flow-driven case, a similar laser irradiance creates a supersonic Sn flow in vacuum. The flow is impeded by an obstacle, which creates a reverse shock, which will also experience high compression due to radiative energy losses. The evolution of both systems was studied with multiple diagnostic techniques. The data will be compared to results from the 3D radiation-hydrodynamic code developed at our Center for Radiative Shock Hydrodynamics.

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-NA0001840, and by the National Laser User Facility Program, grant number DE-NA0000850.

The thermodynamic response of silicate minerals after meteoritic impacts: Implications for the evolution of planetary atmospheres

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Oral

Atmospheric pressure and compositions are among the key important boundary conditions to investigate the evolution of the surface environment of planets. Frequent hypervelocity impacts at the heavy bombardment period are thought to play a key role in the origin and evolution of planetary atmospheres. Shock compression and subsequent rapid decompression induce a variety of physical and chemical processes. The understanding of physical/chemical behavior of impact vapor plumes is important to investigate the number of geological events at that time. Impact-driven processes, however, have not been understood well because of the lack of reliable experimental data on impact-induced vaporization due to experimental difficulties.

In this talk, we describe our experimental approaches for understanding impact-induced vaporization. Recently, high-power lasers used in the studies on nuclear fusion allow us to address extreme conditions on a phase space produced by >10 km/s impacts in a laboratory. We conducted a series of laser shock experiments using silicate minerals. Then, we applied the results to the geological problems, including atmospheric blow-off on the early Earth and Venus and abiotic O2 production on early Mars.

Progress on the White Dwarf Photosphere Experiment on the Z Machine

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Oral

We present the current status of the White Dwarf Photosphere Experiment at the Z Pulsed Power Facility at Sandia National Laboratories. This experiment has evolved into a unique platform for simultaneously measuring emission, absorption, and backlighter continua spectra of plasmas with white dwarf (WD) photospheric compositions and conditions (Te ~ 1 eV, log ne ~ 16 — 18); our current experiments involve line profile measurements of hydrogen—corresponding to the most common surface composition in white dwarf stars, with future experiments planned for helium, carbon, and oxygen. These profiles will test line broadening theories used in white dwarf model atmospheres to infer the fundamental parameters (e.g., effective temperature and mass) of thousands of WDs. This experiment uses the large amount of X-rays generated from a z-pinch dynamic hohlraum to radiatively drive plasma formation in a gas cell. We reach significantly higher densities than the landmark studies of Wiese et al. (1972), thereby putting competing line broadening theories to the test in a regime where their predictions strongly diverge. The simultaneous measurement of emission, absorption, and backlighter continua in macroscopic plasmas represents a significant advance relative to hydrogen line profile experiments of the past.

Supernova Explosions: From Engine to Remnant

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Oral

Our gourp, Astrophysical Big Bang Laboratory in RIKEN, has been established on 1st April, 2013. Our group's research is related to stellar explosion: Supernova Explosion. We are studying central engine of core-collapse supernova explosion, explosive nucleosynthesis, shock breakout, and supernova remnant. We are also studying gamma-ray bursts, some of which are accompanied by peculiar supernovae. Sometimes we are using supercomputers for our research, including K-Computer that is one of fastest super-computers in the world. In this talk, I would like to report summary of our recent and future research activity.

This talk is an invited talk (Thank you very much for the organizers of HEDLA2014).

Invited review: Star and Planet Formation

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Oral

The formation of stars and planets are central topics in astrophysics. Although many issues are still controversial, the main aspects of star formation are becoming increasingly well understood, not the least as a result of increasingly realistic numerical simulations. The multi-faceted roles of supersonic and super-Alfvénic turbulence, which both facilitates star formation and makes it inefficient are becoming increasingly clear, with the gravity assisted fragmentation of mass in space and the corresponding probability distribution function for mass density entering as central properties, which in the end are responsible for shaping the Initial Mass Function -- the apparently nearly universal distribution of initial stellar masses. The rate at which transformation of dense, molecular gas into stars take place – the Star Formation Rate – is another central property, which turns out to mainly be controlled by the 'virial number'; the ratio of average kinetic to gravitation energy density. Using adaptive mesh refinement, with 'sink particles' representing newborn stars, it has recently become possible to follow the star formation in great detail, with the range of scales spanned by single numerical simulations reaching of the order of a billion, allowing the formation of protoplanetary disk to be modeled in realistic Giant Molecular Cloud settings. When combined with observations, which are now beginning to be able to resolve protoplanetary disk in nearby star forming regions, and evidence from studies of isotopic evidence carried by meteorites in our own solar system, a similar dramatic improvement in our understanding of planet formation may be expected in the near future.

Multidimensional modelling of stellar core collapse and explosion

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and
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Oral

Potentially observable across the electromagnetic spectrum, in neutrinos, and in gravitational waves, core-collapse supernovae and gamma-ray bursts mark the birth of neutron stars or black holes. Their evolution involves a wide range of physics acting on a broad range of spatial and temporal scales. In particular, multi-dimensional (magneto-)hydrodynamic instabilities play a crucial role in stellar core collapse and explosion, requiring a highly accurate multi-dimensional modelling of the microphysics of the matter, the fluid flow, the neutrino radiation, and the magnetic field. Due to the complexity, this tasks has been addressed by combinations of different physical approximations and numerical methods. I will discuss simulations focusing on hydromagnetic instabilities and their impact on the large-scale dynamics of the core and present models connecting the explosion to observables and specific events.

Generation of spherical radiative shock waves from ICF implosions

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Oral

Spherically expanding radiative shock waves have been created from inertially confined implosion experiments at the National Ignition Facility. Here, details of these experimental results will be presented and their similarity to astrophysical events will be discussed. In these experiments the principle observable was the temporally and spatially resolved x-ray emission from shock-heated matter. The width and laboratory frame velocity of this emission is observed to remain approximately constant at

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Magnetic reconnection process in the core of toroidal plasmas

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Oral

Two dimensional (2-D) images of electron temperature fluctuations with high temporal and spatial resolution have been employed to study the sawtooth oscillation (m/n=1/1 mode) in toroidal devices. Review of the physics of the sawtooth oscillation is given by comparative studies with prominent theoretical models suggest that a new physics paradigm is needed to describe the reconnection physics of the sawtooth oscillation. A violent disruptive behavior which varies from a simple to an extremely complex burst (multiple relaxation processes) for the same global plasma condition. The degree of non-axisymmetric deformation of the internal magnetic structure prior to disruption influences the outcome of the disruptive behavior. These are critical for the building block of first principle based theoretical modeling of the sawtooth oscillation in current driven toroidal plasmas and the understandings can be applied to the impulsive disruptive behavior in flares of the solar, accretion disk and stellar coronae, and Earth magnetospheric storm.

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What you do and do not get from V&V

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Oral

The reality is that verification and validation (V&V) can be thought of as a rearticulation of the scientific method. As such, and keeping to a basic level there is not much new in V&V. On the other hand, the poor quality of actual V&V practice in many uses of computational science would argue for the need of a particular focus on the topic. Such a focus on V&V first began in engineering communities and transferred to high energy density physics through the USA's ASCI program through the leadership of Sandia National Laboratory (not coincidently a Laboratory with an acute engineering focus). The impetus for V&V focus was the charter of ASCI to develop a predictive capability for stewardship of the nuclear weapons stockpile of the United States without testing. This devotion and focus on V&V is a direct descendent of the desire for predictivity.

In executing the program, many lessons have been learned often by making dire mistakes. These lessons can serve future efforts well if they are learned. Among the hardest lesson is the unnatural, but common separation of computation and experiment (observation). Both means of investigation are greatly assisted by the other, and the conduct of science is improved by their being joined. A second lesson is the leap toward validation of models (and concomitant calibration) without attention to the foundational work in software quality, verification and low-level model validation. All of these activities are more difficult after the fact, and necessary for predictive capability. Among the most pernicious difficulties is the innate desire to minimize the uncertainty associated with prediction. Often the true magnitude of uncertainty is uncomfortably large, and efforts that minimize its true magnitude are encouraged. This serves no purpose other than to quiet the doubts that should cloud the mind and should be the focus of intense investigation. Perhaps the most difficult lesson is how to collaboratively engage in V&V. Experts in V&V are often viewed unfavorably by parts of the community, and the conduct of V&V must work to moderate this trend. This is in part due to the focus of V&V in pointing out uncertainties that make people uncomfortable.

Non-LTE Effects in Radiation-Hydrodynamics Simulations

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Oral

High-fidelity radiation-hydrodynamics simulations have become a critical component in designing and interpreting high energy density laboratory experiments. Advances in algorithms, material properties databases, and computer architectures have combined to increase computational capabilities, resulting in higher fidelity simulations than were possible only a few years ago. The fidelity also depends on the underlying physics models and approximations used in a simulation code. We focus here on the common approximation that local thermodynamic equilibrium (LTE) remains valid for the conditions and timescales accessed in a given simulation. This assumption leads to vast simplifications in computational complexity, as it allows us to specify and tabulate material properties as functions of a small number of variables. For the same reason, it also leads to simplifications in the algorithms. Many radiation-hydrodynamics codes, including those that simulate non-LTE physics, use algorithms that depend on this assumption to some degree.

We consider physical effects and computational issues that arise when the approximation of LTE is not valid. In the non-LTE case, material properties depend on the radiation field, or may even depend explicitly on time. This affects the specification and compilation of physical properties, with consequences for algorithms. We describe computational methods currently used for non-LTE simulations. Examples from the fields of high energy density physics and inertial confinement fusion will demonstrate these effects and identify some remaining computational challenges.

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

Structure of reverse shocks formed in the collision of a supersonic, magnetized plasma flow with a planar obstacle

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and
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Oral

We present data from a HEDP experiment, showing the formation of a reverse shock in the collision of a high Mach number, magnetized, 1D plasma flow with a planar foil obstacle. The plasma flow is formed from the ablation of aluminium wires in an inverse configuration of the wire array z pinch, and is characterised by the advection of a frozen-in magnetic field (1-2T, ReM~50-200), sufficiently strong to affect the structure of the reverse shock.

Results show that in addition to the formation of a stagnation shock at the surface of the obstacle, a detached ‘sub-shock' feature is also detected at a distance of order 1.5c/ωpi (~2-3mm) upstream from the obstacle. Measurements using Thomson scattering and laser interferometery show that the sub-shock displays only relatively small jumps in the flow velocity and plasma density, and low level heating, despite the high Mach numbers (MS~5, MA~8, MMS=4.5) of the flow.

The thickness of the sub-shock feature is relatively small (<100μm); smaller than the ion Lamor radius (~2mm) but at later time comparable to the ion-ion collisional mean free path (200μm) calculated for the interaction of the flow with the decelerated sub-shock plasma. Measurements of the magnetic field with inductive probes and Faraday rotation show the accumulation of magnetic flux behind the sub-shock. It is argued that the interaction of this increased field with the magnetized electrons acts to decelerate the flow through the formation of a dispersively generated, cross-shock potential.

Magnetised shocks in current-driven counter-streaming plasma jets

Francisco SUZUKI-VIDAL – Invited speaker
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Oral

The presence of shocks in jets from young stellar objects can be broadly divided into a series of small, weak, internal shocks along the length of the jet, and large, terminal bow-shocks from the interaction of the jet with the interstellar medium. Their formation and dynamics are governed by a complex interplay between highly-variable flows, cooling instabilities and the presence of magnetic fields generated at the launching region, making these shocks a highly-challenging scenario for numerical codes and experiments.
We present a new experimental platform that aims at reproducing the dynamics of shock formation in young stellar jets by the collision of two counter-streaming plasma jets. The colliding flow geometry aims at modelling a jet-ambient interaction and the effects on the formation of a bow-shock.
The jets are magnetically-driven by a strong electrical current from the MAGPIE pulsed-power generator (1.4 MA, 250 ns). The current is introduced into two aluminium "radial foils" connected in series, which generate opposite plasma jets/outflows expanding in vacuum. The plasma is characterised by typical flow velocities of ~100 km/s, electron densities ~10^{18-19} cm-3 and temperatures of ~15 eV. The plasma is in the collisional regime and has the unique feature of an embedded toroidal magnetic field which plays an important role in the shock dynamics.
The collision between the jets produces two main shock features: a radially extending laminar, double-shock structure roughly at the midpoint between both foils, and a "clumpy" bow-shock on the axis of both foils. The presence/lack of instabilities can be interpreted as suppression of cooling instabilities by the presence of a magnetic field in the shocks. Experimental data are compared with numerical simulations with the 3-D MHD code Gorgon, and the effects of radiative cooling in the plasma are analysed from collisional-radiative simulations using the codes ABAKO and RAPCAL.

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In collaboration with:
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Interface Physics in Laboratory and Astrophysical Plasmas

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Oral

Interfaces between materials with contrasting temperatures are important in both laboratory and astrophysical plasmas. Observations of filaments in galaxy halos highlight the interaction of molecular and atomic material between 100 and 10,000 K with an environment with a temperature in the keV range. Similar physics will be important at shocks and interfaces in fusion reactors, such as ICF capsules and tokamaks. This presentation will discuss the approaches which have been used to model these interfaces, and the challenges to these models from experiment and observation.

Theory and modeling of thermonuclear supernova flames

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and
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Oral

Thermonuclear supernova (SNIa) is an observable result of a total disruption of a compact white dwarf (WD) star, powered by thermonuclear transformation of its degenerate carbon-oxygen matter into heavier elements. A significant part of this transformation occurs in a flame with a submillimeter thickness during the initial deflagration stage of the explosion. Modeling the flame propagation through the WD is challenging due to small scales of the flame instabilities, which cannot be resolved in full-star scale simulations. We review the physics of such thermonuclear flames and the ways used to model these in large-scale simulations. Instabilities of the flames and corresponding models are discussed, in particular Rayleigh-Taylor instability that is dominant for the SNIa flame at large scales, and Landau-Darrieus instability important in the models.

The study of magnetic reconnection with Shenguang II lasers

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and
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Oral

Recent laser driven magnetic reconnection (LDMR) constructed with self-generated B fields has been experimentally and theoretically studied extensively [1-5], where more than Mega-Gauss strong B fields are spontaneously generated in high-power laser-plasma interactions, which located on the target surface and produced by non-parallel temperature and density gradients of expanding plasmas. For the properties of short lived and strong B fields in laser plasmas, laser driven magnetic reconnection opened up a new territory in a parameter regime not covered before. In this talk we will present the recent LDMR experimental results performed on Shenguang II lasers, which is aimed to understand the basic physical processes, such as particle accelerations, scale of diffusion region, and guide fields effects et al.

CONTRIBUTED TALKS

Studying the evolution of hydrodynamic instabilities using high power lasers

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Oral

The evolution of classical as well as ablatively stabilized perturbed interface is of high importance to Inertial Confinement Fusion and High Energy Density physics research.

In this talk we shall describe recent theoretical work regarding the convergence to asymptotic self similar behavior and its connection to experiments and simulations of Rayleigh-Taylor, Richtmyer-Meshkov and Kelvin Helmholtz evolving from 1, 2, and multimode initial perturbations. The highly challenging experiments needed to confirm the new theoretical predictions of the self-similar power laws will be discussed.

Progress and status of ZAPP: The Z astrophysical plasma properties collaboration

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Oral

The Z Astrophysical Plasma Properties (ZAPP) collaboration addresses a question in astronomy: How do the fundamental radiative properties of matter affect the formation, evolution, structure, and spectral emission of astrophysical objects? Laboratory plasma conditions that address outstanding astrophysical puzzles are generated using x-rays from the MJ-class Z facility at Sandia National Laboratories. Plasmas conditions span electron densities and temperature in the 1e16-23 e/cc and 1-200eV ranges, respectively, in LTE or nLTE radiation-dominated conditions. A unique and important attribute of these High Energy Density plasmas is the relatively long-lived duration, uniformity, and large volumes (mm3 to 100cm3). The copious x-rays simultaneously drive four separate physics experiments on each Z shot, presently investigating, stellar interior opacities, AGN warm-absorber photoionized plasmas, spectral line emission from photoionized plasmas near accretion powered objects, and line shape formation in white-dwarf photospheres. The goal is to provide well-characterized experimental data to critically benchmark atomic and kinetics physics codes that simulate the fundamental radiative properties of HED plasmas, and consequently provide answers to the astrophysical community. The extended suit of diagnostics and data processing tools allows collecting and analyzing large amounts of data: we record up to 59 individual spectra on a single shot. This presentation will give an overview of ZAPP status and results, with emphasis on Fe and Ni opacity measurements at conditions approaching the base of the solar convection. We will present high-resolution absorption spectroscopy measurements aimed improving knowledge of photoionized plasma spectral line formation and the influence of Resonant Auger Destruction on spectra emerging from accreting material in x-ray binaries.

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

FLASH magnetohydrodynamic simulations of experiments that study shock-generated magnetic fields

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and
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Oral

We summarize recent additions and improvements to the high energy density physics capabilities in FLASH, highlighting new non-ideal magnetohydrodynamic (MHD) capabilities. We then describe 2D cylindrical and 3D Cartesian FLASH MHD simulations that have helped to design and analyze experiments conducted at the Vulcan laser facility. In this experiment, a laser illuminates a carbon rod target placed in a gas-filled chamber. A magnetic field diagnostic (called a Bdot) employing three very small induction coils is used to measure all three components of the magnetic field at a chosen point in space. The simulations have revealed that many fascinating physical processes occur in the experiments. These include magnetic fields generated by an outward expanding shock via the Biermann battery mechanism; Megagauss magnetic fields generated by the interaction of the laser with the target via the Biermann battery mechanism, which are advected outward by the vaporized target material but decrease in strength due to expansion and resistivity; and a breakout shock that overtakes first the contact discontinuity between the target material and the gas, and then the initial expanding shock. Finally, we discuss the validation and predictive science we have done for this experiment with FLASH.

This work was supported in part at the University of Chicago by DOE NNSA ASC.

Formation of Radiatively Cooled, Differentially Rotating, Plasma Disks in Z-pinch Experiments

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Oral

This work aims to develop an experimental platform with which to study laboratory plasmas relevant to astrophysical accretion disks. The approach taken is complementary to laser driven work proposed by Ryutov [1] and builds on principles demonstrated in earlier work [2] for introducing angular momentum to plasma outflows generated by a z-pinch system.

Formation of a rotating disk is achieved through the addition of angular momentum to the converging ablation flows from a cylindrical wire array z-pinch. Angular momentum is generated by introducing a cusp magnetic field such that both and are present at the wires. The cusp field is produced by opposing coils above and below the array driven by the same current as the wires.

Experiments show the formation of a supersonically rotating hollow disk (Mach 1-2, diameter ~ 3mm) which is sustained by the ram pressure from the converging flows for ~ 200 ns. Laser interferometry is used to measure the density of the disk (>1018cm-3) whilst Thomson Scattering provides direct measurement of the velocity distribution of both the converging flows and rotating disk. Measurements from a multi-frame XUV camera show the formation of an initially smooth and uniform disk which becomes highly perturbed by internal processes later in the experiment. Results from these experiments are compared to numerical simulations made using the GORGON code [3].

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Collisionless shock experiments using large-scale lasers

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Collisionless shocks, in which a coulomb mean-free-path is longer than the shock-front thickness, are considered to be sources of high-energy particles or cosmic rays. In collisionless plasmas wave-particle interactions and collective effects play an essential role in the shock formation. A laboratory experiment can be an alternative approach to study the formation of collisionless shocks in addition to local observations of spaces plasmas by spacecraft and global emission measurements of astrophysical plasmas.

In this paper, we investigate the formation of electrostatic collisionless shocks in counter-streaming plasmas produced by Gekko XII HIPER system. Shock structures were measured by optical diagnostics (interferometry, shadowgraphy, self-emission), and collective Thomson scattering diagnostics provide electron density, electron and ion temperatures, flow velocity, and Mach number in the upstream and downstream regions of a shock. We also investigate experimental plans to demonstrate the formation of Weibel-instability mediated collisionless shocks using the National Ignition Facility.

One-to-one PIC modeling of laboratory studies of collisionless shocks

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Collisionless shocks are ubiquitous in astrophysical plasmas and are believed to be responsible for particle acceleration; however, the microphysics underlying shock formation and particle acceleration is not yet fully understood. Recent developments in high-power lasers are bringing the study of collisionless shocks into the realm of laboratory experiments. We have performed detailed 2D and 3D particle-in-cell simulations with OSIRIS and Tristan-MP to explore the laboratory conditions associated with counter-streaming high-velocity plasma flows for realistic density and temperature profiles. We capture all the relevant physics, which range from the generation of Biermann battery fields at the laser-foil region, to collisional effects, and the micro-instabilities associated with the counter-streaming flows. We also incorporate proton radiography diagnostics in our simulations. We will discuss the difference between current Omega conditions, where Weibel-generated magnetic fields have been observed and are matched by our simulations, and the expected NIF conditions, where a collisionless shock can be generated. We show the importance of taking into account the role of Biermann battery B-fields to build a complete picture of the interaction. We also estimate neutron yields for the case of shock heated Deuterated flows, determining an important experimental signature of collisionless shocks. Our work identifies the optimal conditions for the formation of collisionless shocks in laboratory, showing the possibility of observing for the first time Weibel-mediated shocks in near future NIF experiments.

Inertial collimation mechanisms in nested outflows

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Strong interactions between a central collimated outflow and a surrounding wind are common in astrophysics. This includes young stellar objects (YSOs) where a connection between accretion discs, outflows and jets has long been established [1], as well as dying stars in the planetary nebula (PN) phase [2], where fast winds from the PNs central star expand into an aspherical slow wind. Outflows from active galactic nuclei (AGN) also exhibit some combination of collimated and broader components [3]. Understanding how the interaction might contribute to the collimation of an otherwise uncollimated outflow is of particular interest for assessing jet formation paradigms [4]. Here we present an experimental approach aimed at investigating the interaction between two nested supersonic plasma flows, generated with a high energy long pulse laser beam. Our results show clear evidence for the formation of very collimated jets by inertial collimation of an inner outflow nested within an outer outflow. Our experimental data combined with hydrodynamic simulations confirm the so-called "shock-focused inertial confinement" mechanism, suggested in previous theoretical astrophysics investigations [5,6].

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Laboratory Investigation of Accretion Shocks at the Orion Laser Facility

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Oral

The aim of the POLAR project[1] is to simulate, in the laboratory, the accretion shock region of a binary system of a late sequence star transferring matter to a highly magnetised (B~10-230 MG) white dwarf. Investigation into hydrodynamic scaling laws have shown that laboratory experiments can be related to astrophysical phenomena by matching the relevant dimensionless parameters[2,3].

The POLAR experiment at the Orion laser facility utilised high intensity laser pulses to drive a flow of plasma into an obstacle, which was collimated by a tube. X-ray and optical diagnostics were utilised to diagnose the region in front of the obstacle, where a reverse shock was expected to form; analogous to the impact region on the surface of the white dwarf. Results from this experiment are presented here, which help to show more clearly the dynamics of this system. Comparison to simulation and the astrophysical case are also shown.

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Studies of Shock Waves and Related Phenomena Motivated by Astrophysics

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In our Center for Laser Experimental Astrophysics Research, we pursue a range of experiments involving shock waves and ultimately motivated by astrophysics; this presentation will provide an overview of our recent laboratory astrophysics research. We lead some experiments and collaborate in others; the focus here will be on the experiments we lead.
We study magnetized, flowing plasmas by using shocked matter as a plasma source to create desired configurations. We have used driven shocks and oblique shocks in a flow to produce a plasma jet source of long duration, and have done experiments to characterize these jets. Motivated by some observational issues in T-Tauri stars, we are now studying the collision of a collimated jet with a surface, with and without magnetization. This is the thesis research of Rachel Young. We will discuss the scaling between this system and the analogous collision in T-Tauri stars.
Our recent work with radiative shock waves has focused on radiative reverse shocks, which form when a sufficiently fast flow is impeded in some way. We produced the first laboratory radiative reverse shock and have observed these shocks in collisions at normal or oblique incidence. This was the thesis research of Christine Krauland. We will discuss their connection with the hot spot in Cataclysmic Variable stars having an accretion disk, and the scaling between these stars and the laboratory.
We also study fundamental hydrodynamic processes that occur in astrophysical and other environments by using shock waves to produce the necessary conditions. We will discuss results of recent work of this type, in which various experiments are focused on the Richtmyer Meshkov, Kelvin Helmholtz, and Rayleigh Taylor processes. This is thesis research by Carlos Di Stefano and Wesley Wan. Recent results include the first Richtmyer-Meshkov experiment to directly detect mode coupling, the first supersonic, non-turbulent Kelvin-Helmholtz experiment, and evidence of mode coupling in subsonic Kelvin-Helmholtz.

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Energy transfer, stochastic heating and radiation emission in counter-propagating plasmas at sub-relativistic velocities

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Collisionless shocks are frequent events in the interstellar medium, they can also take place in inertial fusion targets where high energy ion beams interact with target plume plasma. The understanding of these processes is consequently important from a theoretical point of view and for laboratory laser-plasma interaction experiments. Large scale Particle-In-Cell simulations are widely used to give crucial information on the shock evolution and the energy dissipation. They also give access to ion and electron particle and energy densities and electromagnetic fields, authorizing energy transfer analysis from the ions to electrons and fields.

In this communication, we consider interaction of two counter-propagating homogeneous sub-relativistic plasma beams with no external magnetic field applied. In numerical simulations performed with a Particle-In-Cell code three stages of evolution can be identified. The shock formation is initiated with development of the electron-ion Weibel-like micro-instabilities, followed by fast electron heating and ion de-acceleration and heating. We present a theoretical analysis of the instabilities development and nonlinear saturation to explore the origins of the heating and the magnetic field generation. Electrons are assumed relativistic and cold ions are counter-propagating with sub-relativistic velocities. From the dispersion relation, instability is characterized and dependence on the electron temperature and ion velocity is studied. The growth rate and the characteristic scales of instability are compared to simulation results. The role of quasi-static electric fields in the instability development is discussed. Electron heating is analysed and compared to a model of stochastic heating in fluctuating fields.

Radiation by fast electrons is obtained from these Particle-In-Cell simulations and characteristic signatures that could be useful for future experiments are discussed. This approach provides global view of the instabilities induced in the interaction process and generating collisionless energy transfer between ions and electrons.

Long duration drive hydrodynamics experiments relevant for laboratory astrophysics

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The advent of high-power lasers facilities such as NIF, and LMJ PETAL in the near future, opens a new era in the field of High Energy Density Laboratory Astrophysics. These versatile laser facilities will provide unique platforms to study the rich physics of nonlinear and turbulent mixing flows because targets could be accelerate over much larger distances and longer time periods than previously achieved. We will report on the first results acquired on NIF with the ablative Rayleigh-Taylor Instability (RTI) platform [1]. A 20-ns x-ray drive is tailored to accelerate planar modulated samples into the highly-nonlinear bubble merger regime. Based on the analogy between flames front and ablation front, highly nonlinear RTI measurements at ablation front can provide important insights into the initial deflagration stage of thermonuclear supernova of Type Ia [2]. We will also report on innovative concept used to create even longer drive on multi beam laser facilities. The multi-barrel hohlraum ("Gattling Gun") approach consists of three adjacent cavities, driven in succession with three 10ns pulse UV beams on the Omega EP laser system [3]. A 30 ns, 90 eV x-ray radiation drive was measured with the time-resolved x-ray spectrometer µDMX. This concept is promising to investigate the pillar structures in the Eagle Nebula or photoionization studies require a steady light source of sufficient duration to recreate relevant physics [4].

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A two dimensional, singlemode KH experiment on EP

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The Kelvin-Helmholtz (KH) [7, 9] instability evolves between two fluid regions flowing past one another, producing a shear layer between them with a velocity difference Δu. The instability evolves as small modulations initially located on the shear layer grow in the form of vortices (i.e. rollups), eventually forming a mixing zone (MZ). This instability is of high importance in many physical and engineering systems having a large variety of length scales, such as deep ocean waves [11], atmospheric shear flows [10], inertial-confinement-fusion capsules [1], astrophysical systems such as deflagrations in supernovae [2], protoplanetary disks [3], non-spherical core-collapse supernovae [6] and astrophysical jets [4], and flows in engineering systems such as supersonic jet planes and rocket engines [5]. In many of these applications, the KH evolution is done in the supersonic regime. In this regime, compressibility effects become dominant, and the growth rate of the instability is inhibited in comparison to the classical, non-compressible regime. In this presentation, we describe the design of an experiment to study KH evolution in the supersonic regime and we show preliminary results from the experiment. The design, reported by Malamud et al. [8], enables observation of the development of KH from a two- dimensional, single-mode, initial perturbation. The experimental platform convective Mach and Atwood numbers were ~ 0.85 and ~ 0.8, respectively. Preliminary analysis of the experimental data, from Omega EP, indicates that we did observe a reduction in the rate of growth. We will compare the data and simulations.

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Shock waves and star formation using multigroup radiation hydrodynamics

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Radiative transfer plays a major role in the field of astrophysics since it provides all the information we know about the universe. In many cases, as for example in stellar atmospheres, the radiation is considered as a physical probe which provides access to the thermodynamical properties of the flow through the spectrum of emission and absorption lines. However, the radiation often has a very important dynamical role in the system. It cannot only be considered as a passive probe, but as an integral part of the equations governing the system dynamics.
As the radiation intensity depends on seven variables in 3D, solving the full transfer equation coupled to the hydrodynamics to tackle radiation hydrodynamics problems is still out of reach of modern computational architectures. In order to overcome this difficulty, much effort has been spent in recent years developing mathematically less complicated, yet accurate approximations to the equations of radiative transfer. Such approximations use frequency and/or angle-integrated variables. Yet, the absorption and scattering coefficients almost always depend strongly on frequency, and the grey approximation is no longer appropriate. I will present a multigroup model for radiation hydrodynamics to account for variations of the gas opacity as a function of frequency.
We have applied the method to the study of the structures of radiative shocks in Ar using the HERACLES code. We show that using even a small number of frequency groups can significantly influence the dynamics and morphologies of subcritical and supercritical radiative shocks, and in particular the extent of the radiative precursor.
We have also used the method in simulations of star-formation, in conjunction with a non-ideal gas equation of state as well as an extensive set of spectral opacities to model the first and second phases of the collapse of a molecular cloud core to form the first and second Larson cores. We find that the first core accretion shock remains supercritical while the shock at the second core border is strongly subcritical with all the accreted energy being transfered to the core, and that the size, mass and temperature of the second cores are independent of the parent cloud properties.

Ultra-intense Pair and Gamma-ray Creation using the Texas Petawatt Laser and Astrophysical Applications

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Pair plasmas and intense gamma-ray sources are ubiquitous in the high-energy universe, from pulser winds to gamma-ray bursts (GRB). Their study can be greatly enhanced if such sources can be recreated in the laboratory under controlled conditions. In 2012 and 2013, a joint Rice-University of Texas team performed over 130 laser shots on thick gold and platinum targets using the 100 Joule Texas Petawatt Laser in Austin. The laser intensity of many shots exceeded 10^21 W.cm^-2 with pulses as short as 130 fs These experiments probe a new extreme regime of ultra-intense laser - high-Z solid interactions never achieved before. In addition to creating copious pairs with the highest density (>10^15/cc) and emergent e+/e- ratio exceeding 20% in many shots, these experiments also created the highest density multi-MeV gamma-rays, comparable in absolute numbers to those found inside a gamma-ray burst (GRB). The total emergent gamma-ray fluence was comparable to those seen by the ISM at a distance of around 10 pc from a GRB. Potential applications of such pair and gamma-ray sources to laboratory astrophysics, including the destruction of interstellar dust grains, will be explored.

Opacity experiments for stellar physics on LMJ+PETAL

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Asteroseismology (SoHo, CoRoT, KEPLER) has already measured the most penetrating acoustic oscillations of thousands of solar type stars. Their travelling times largely depend on the thermodynamical conditions of their very extended radiative zone. In the solar case, the radiative zone extends on 70% in radius but 98% of the mass and the sound speed profile is extracted from the observations. The physics, that one hopes to validate on the Sun, is then used to interpret the seismic results of other stars for which one deduces radius, age and mass with unprecedented accuracy.
In this context, the production of energy and the transport of energy must be under control as they play a key role. The same kind of knowledge is also necessary for fusion produced by lasers or tokamaks.
In solar-like stars, the energy transport is dominated by the interaction of photons with the different species of the plasma. At the relevant temperatures and densities, hydrogen and helium are totally ionized, but the other species are generally only totally ionized near the centre and then experience different stages of ionization that must be established. This fact increases the photon interaction with matter up to a limit where the convection becomes more efficient to extract the energy.
So, even if their relative mass is small, about 25 species play a role in this interaction, and it is thus necessary to characterize precisely the interaction of the photons (opacity) on these different species on a large range of temperature (2 - 15.10^6 K) and density (0.2 - 150 g/cm^3).
The width of the lines (bound-bound processes) and the plasma effects need to be validated by experiments. The LMJ, coupled with PETAL, is a very appropriate tool to deal with these issues, so we present a design of an opacity experiment on this facility, aiming at measuring solar opacities, and we discuss the required experimental setup that we need to build to realize such experiment.

Fast Magnetic Reconnection From Taking into Account Electron Inertia and Hall Physics

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Magnetic reconnection is one of the least understood phenomena in plasma physics and yet one of the most important because it enables plasma magnetic topology to change and, in addition, it provides a means for converting magnetic field energy into particle and wave energy. If magnetic reconnection did not exist, no magnetized plasma could ever separate from or join any other magnetized plasma and there would be no obvious mechanism for the creation of observed energetic particles and waves.
Magnetic reconnection is traditionally modeled in a two-dimensional plane using finite-resistivity magnetohydrodynamics (resistive MHD) to describe a highly localized diffusion of magnetic field across the plasma at an X-point. While the predictions of resistive MHD are qualitatively consistent with observed behavior, the predicted quantitative reconnection growth rate is typically too slow by many orders of magnitude. It is now generally believed that collisionless, non-MHD two-fluid or kinetic theories must be used to model reconnection if quantitative agreement with the fast observed behavior is to be obtained. These non-MHD models (and also particle-in-cell numerical simulations) indicate that a non-MHD, out-of-plane magnetic field exists in the vicinity of the X-point. This out-of-plane magnetic field reverses polarity on moving from any X-point quadrant to its neighbor and so is called a quadrupole magnetic field. The quadrupole field is derived by taking into account the interaction of Hall terms in the generalized Ohm's law with the gradient of the current density. The quadrupole magnetic field has recently been observed by spacecraft traveling through reconnection layers in Earth's magnetosphere and also in recent laboratory experiments. Manifestation of the quadrupole field is usually considered to be a clear signature of non-MHD reconnection.
Models to date have focused on how the quadrupole is generated but not on what it does. Furthermore, non-MHD reconnection models to date have paid little attention to the implications of finite electron inertia; electrons have typically been assumed to be massless so behavior at the electron skin depth scale has not been resolved. We describe here a model that incorporates electron inertia, the Hall term, and the finite extent of the reconnection region. This model shows that the quadrupole field is not just a signature of non-MHD reconnection, but in fact constitutes a critical component of the dynamics underlying fast reconnection. Coupled equations resolving behavior at the electron skin depth scale show that the quadrupole magnetic field feeds upon the parallel vector potential and vice versa to produce an extremely fast reconnection rate. By solving an eigenvalue problem analogous to that of a quantum mechanical bound-state, the reconnection e-folding growth time is shown to be of the order of the Alfven time and so orders of magnitude faster than the predictions of resistive MHD.

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NEW RESULTS ON THE SEDOV–TAYLOR POINT EXPLOSION LINEAR STABILITY: APPLICATION TO RYU–VISHNIAC AND VISHNIAC INSTABILITIES

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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 (ST) regime [4] described by a well understood self-similar expansion, *R(t)=t^(2/5)*, and third a radiative stage with *R(t)=t^q* and q between 1/4 and 2/5, where the radiative cooling of the expanding flow produces the formation of a thin dense cold shell until the internal pressure of the shell produces its expansion and the end of BW. The stability of the ST stage has been recurrently investigated in the literature from the Ryu-Vishniac pioneer work [5]. The lack of a rigorous analytical analysis in the past, has been the cause of all controversial and questions posed around the Ryu-Vishniac instability, and hence about Vishniac instability [6], and the differences, if any, with Raleigh-Taylor instability. The getting of a rigorous analytical analysis, and its physical consequences, is the goal of the present work. The correct determination of the eigenvalue's spectrum (s) is very important and crucial in order to know what kind of temporal behavior [t^s] could be observed in the nature in a physical problem, which could be, experimentally or by means of numerical simulations, reproduced. The total spectrum is completely determined in this work, including too, for the first time, the continuous spectrum. Then the conditions for the existence of eigenmodes of type t^s, depending on the perturbation wave number and the adiabatic index, are physically well clarified and discussed.

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Modeling high-energy astrophysics phenomena with ultra-intense lasers

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Relativistic electron-positron plasmas are essential element in researching high-energy astrophysics phenomena. In the laboratory, positron production has been studied theoretically[1] and experimentally and a series of experiments is reported by Hui Chen with several ultra-intense lasers in the world[2]. But, these electron-positron plasmas can't be called plasma because the Debye length is almost the same as the plasma size[3]. It may be possible to create relativistic electron-positron fireball with use of induced vacuum breakdown triggered by the Briet-Wheleer process between the gamma-ray produced by radiation damping of electrons and created positrons and laser photon[4]. We are carrying out the composition of computer code[5] including QED and non-linear QED effects[6] in three dimensional PIC code. We will clarify how much percent of laser photon energy is converted to electron-positron fireball energy and characteristics of the fireball in order to know if we can do model experiments in the laboratory regarding relativistic electron-positron plasma phenomena predicted theoretically in high-energy astrophysics

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Structure and Dynamics of Colliding Plasma Jets

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Oral

Proton images of unprecedented clarity reveal the structures and dynamics of pairs of laser-generated, high-Mach-number plasma jets that collide at various angles. The measurements are modeled with hydrodynamic simulations and analytical analysis. The jet streamlines indicate that the colliding plasma electron flows stagnate in the interaction region and subsequently spread sideways along the bisector plane due to the rarefaction expansion. For collisions of two noncollinear jets, the measured electron flow structure is reproduced by an analytical model that predicts a characteristic feature with a narrow structure pointing in one direction and a much thicker one pointing in the opposite direction. Spontaneous magnetic fields, largely azimuthal along the colliding jets and generated by collisional current drive in the interaction region as well as by the Biermann battery effect around the laser spots, are demonstrated to be "frozen in" the plasma electron flow and advected along the jet streamlines. These studies provide novel insight into the interactions and dynamics of colliding plasma jets.

Shock-Cloud Interactions and Triggered Star Formation

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The interaction of shock waves with gaseous clouds represents a fundamental problem in astrophysics with many applications. Shock-cloud interactions also represent a highly successful platform for laboratory astrophysics studies. In this presentation we report on new studies of Triggered Star Formation including, for the first time, tracking the post-triggering flow dynamics in which a newly formed star interacts with ablated cloud material. Besides their application to understanding star formation these studies are relevant to both numerical methods through the explication of strengths and weaknesses of different sub-grid models for the physics as well as HEDLA studies of shock-clouds through articulation of instabilities that occur leading to mixing in the flow.

Star formation can be triggered by compression from wind or supernova driven shock waves that over-run molecular clouds. Because these shocks will likely contain processed elements, triggered star formation has been proposed as an explanation for short-lived radioactive isotopes (SLRI) in the Solar System. Previous studies have tracked the triggering event to the earliest phases of collapse and have focused on the shock properties required for both successful star formation and mixing of SLRI's. In this presentation, we use Adaptive Mesh Refinement (AMR) simulation methods, including sink particles, to simulate the full collapse and subsequent evolution of a stable Bonnor-Ebert sphere subjected to a shock. We track the flow of cloud material after a star (a sink particle) has formed. For non-rotating clouds we find significant gravitational interactions between the star and shocked, in-falling cloud material can lead to upstream-focused flows that overshoot the star. When we add initial cloud rotation we observe the formation of disks which then interact with the post-shock flow. Our results indicate that these disks will be long-lived in spite of ablation driven by post-shock flow ram pressure. We track the evolution of both star and disk properties with time, determining the dependence of accretion rates and mixing ratios with initial conditions.

POLAR Project : laboratory simulation of accretion process onto highly magnetized white dwarf

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Oral

The POLAR Project aims at studying the formation and dynamics of radiative accretion shocks as found in magnetic cataclysmic variables (also called polars, [2]). Polars are the perfect probe to test accretion models in extreme environments and actual models can't explain all observational features. Then numerical, theoretical and experimental approaches are conjugated to astronomical observations to eventually improve the model used to describe those objects [1].

In the POLAR experiments, relevant target design has been elaborated to study accretion processes onto compact objects. We will present rigorous scaling laws supported by numerical simulations which prove that relevant regime could be reached using powerful lasers. Recently, the target design has been improved to get a situation which is closest to the astrophysical one and to simplify the comparison between the experiment and the astrophysical column [3]. Results from the experiment on the LULI2000 laser facility performed in 2012 will be presented along with numerical simulations [4]. Forecast of experimental results onto higher energy facilities will also be discussed as well as the experimental perspectives to such an experiment in order to answer questions raised by the astronomical observations [5, 6].

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Diffusive Shock Acceleration at Shock Waves in the Intracluster Medium

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Oral

Clusters of galaxies are the largest virialized structures in the universe, which serve as laboratories for studies of astrophysical processes on very large scales. The baryonic matter there is in the form of hot, collisionless plasma. Shock waves are induced during hierarchical formation of clusters of galaxies. These collisionless shocks are thought to accelerate cosmic rays (CRs) via diffusive shock acceleration (DSA) mechanism. In this talk, we describe the properties of shocks formed in the intracluster medium and review recent studies of how magnetic field amplification by CR streaming instabilities and Alfvenic drift may affect the DSA efficiency at the shocks. We then discuss the possibility of realization of collisionless shocks in laboratory experiments.

Ultra-fast thermalization of laser-driven ultra-relativistic plasma flows: towards the generation of collisonless pair shocks in the laboratory

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Oral

Collisionless shocks between high-velocity, counter-streaming (electron-ion or electron-positron) plasma flows have been extensively investigated over the past years to gain understanding of various extreme astrophysical scenarii [1]. For fast enough flows, fast-growing electromagnetic instabilities [2] are held responsible for dissipation, Fermi-type particle acceleration and high-energy radiation. Laboratory-scale experiments on such processes will constitute invaluable testbeds of theoretical and observational models, yet their realization remains highly challenging. The most promising path to this goal relies on high-energy-density flows driven by intense lasers. Encouraging results have already been obtained on colliding electron-ion flows from high-energy laser-ablated targets [3]. A more speculative setup considering relativistic-intensity laser interaction with overdense plasmas has also been proposed [3]. The experimental study of electron-positron instabilities appears even more challenging owing to the difficulty of creating dense enough pair plasmas. Current investigations mainly focus on pair production in thick dense high-Z targets via the Bethe-Heitler conversion of Bremsstrahlung-produced gamma photons [4]. Nonetheless, recent theoretical and numerical explorations have demonstrated the capability of next-generation multi-PW lasers to generate overdense pair plasma jets via various QED mechanisms including the Compton emission of gamma photons and the multiphoton Breit-Wheeler pair production [5]. Here, we examine a concept of colliding pair plasmas that exploits the extreme electromagnetic fields envisioned on compressed LMJ-class laser projects. We present the first self-consistent numerical study, using QED-PIC simulations, of the interaction of two counter-streaming, relativistic pair flows driven from laser-irradiated thin Al foils. Fast-growing Weibel instabilities are found to induce ultra-fast thermalization of the pair jets through the buildup of a ~2×10^6 T magnetostatic barrier. The associated gamma-ray generation, as well as the subsequent ion-ion interaction are analyzed in detail. Finally, we will report on the simulation of a laser-driven pair jet interacting with an electron-ion plasma, of relevance for the so-called Fireball model [6].

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Magnetization Effects on Collimated Plasma Jets

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Oral

Magnetized plasma jets are ubiquitous in the universe and found in many classes of astrophysical objects. In many cases these jets are magnetized by a background field where the magnetic pressure is comparable in magnitude to that of the thermal pressure. Recent experiments at the Jupiter Laser Facility investigated the effects of varying degrees of magnetization on a collimated plasma jet. Laser-irradiated plastic-cone-targets produced collimated, millimeter-scale plasma flows as indicated by optical interferometry. These targets were then placed in a custom-designed solenoid that generated field strengths up to 5 Tesla. In these experiments, the magnetic field was aligned with the jet propagation direction, as is the case in many astrophysical instances. Lower magnetization of the jet was found to result in a wider jet envelope than in the completely unmagnetized case. Though at higher magnetization, the jet envelope becomes more collimated as expected.

Core-Collapse Supernova Explosions and Experiments on the National Ignition Facility

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We present and discuss in detail design simulations for a blast-wave driven Rayleigh-Taylor experiment on the National Ignition Facility (NIF). The experiment is relevant to the problem of mixing of nucleosynthetic products in core-collapse supernovae. The current design is intended to serve as a stepping stone for more realistic Rayleigh-Taylor experiments using diverging geometry.

We demonstrate that the experiment can be executed and diagnosed with the experimental capabilities already available on NIF. We explore the resolution dependence of simulation results and study the impact of small-scale secondary perturbations that might be introduced during the process of target manufacturing. We optimze the design to achieve the best possible diagnostic signal-to-noise ratio, the greatest amount of mixing, and the richest morphology of the mixed region. The evolution of the mixed-layer width in the simulations is found to be in excellent agreement with the predictions of a buoyancy-drag model.

Observing two-photon pair production for the first time in the laboratory

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Oral

As the inverse of Dirac annihilation, the Breit-Wheeler process [1], the production of an electron-positron pair in the collision of two photons, is the most simple mechanism by which light can be transformed into matter. It is also of fundamental importance in high-energy astrophysics, both in the context of the dense radiation fields of compact objects [2] and the absorption of high-energy gamma-rays travelling intergalactic distances [3].

However, in the 80 years since its theoretical prediction, this process has never been observed. Here we present the design of a new class of photon-photon collider [4], which is capable of detecting significant numbers of Breit-Wheeler pairs using current-generation laser facilities. Successful implementation of our experimental scheme would represent the advent of a new type of high-energy physics experiment.

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Hydrogen-Water Mixtures in Giant Planet Interiors Studied with Ab Initio Simulations

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With the extraordinary discovery of more than 775 confirmed exoplanets and even more candidates from the Kepler survey, the need for more accurate structure and evolution models becomes very relevant. One important issue for gas and ice giant planets is to determine the behavior of hydrogen-water mixtures in their envelope. It is currently unknown whether a planet contains a dense, hot steam atmosphere or a water ocean that is well separated from a hydrogen atmosphere. Laboratory measurements demonstrated the molecular hydrogen and water phase separate at low pressure and temperature. Recently, computer simulations predicted that water and metallic hydrogen form a homogeneous mixture at pressure of 10 megabars and 3000 K [Wilson, Militzer, ApJ 745 (2012) 54]. The intermediate pressure regime that is of interest for giant planets in our solar system and sub-Neptune exoplanets has not been explored. We present results from ab initio computer simulations in combination with Gibbs free-energy calculations and different thermodynamic integration methods. We determine the pressure-temperature conditions for hydrogen-water phase separation and discuss the consequences for the giant planet interiors. Our findings may have implication for the heat transfer and the distribution of other compounds like ammonia in giant planets envelopes.

Laser experiments on Radiative Shocks relevant to Stellar Accretion

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Strong radiative shocks often occur in stellar environments, and are characterized by high temperatures plasma emitting an important fraction of its energy as radiation. In the case of stellar accretion, matter is funneled into accretion columns by the stellar magnetic field, and falls at several hundreds of km/s from the circumstellar envelope onto the stellar photosphere. This generates a strong radiative shock which emits x-rays, and whose spectral signature is a key ingredient to quantify the mass accretion rate. The physical structure and dynamics of such plasma is complex, and experimental benchmarks are needed to provide a deeper understanding of the physics at play, and for testing radiation hydrodynamics codes, which in turn, are used to model astrophysical phenomena.

Radiative shocks have been studied in high-energy density laboratory experiments using various laser facilities for more than a decade, proving the importance of radiation on the plasma. Among them, the kJ iodine PALS laser facility is known to produce radiative shocks with a velocity of ~50-60 km/s in Xenon gas at a fraction of the bar. The important specificity of this installation is its flexibility to develop novel diagnostics. A unique opportunity of the installation is the most powerful soft x-ray laser available today, namely the Zn laser at 21.2 nm. With the duration of 0.2 ns it opens the door to new diagnostics of dense plasmas. We will present the first instantaneous imaging at 21.2 nm of the precursor and post shock structure of radiative shock generated in Xenon on this installation, and its complementary with a time-and-space resolved XUV plasma self-emission using fast diodes. Interpretation of the data will be presented showing the importance of the radiative processes from atomic to larger scales.

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Collisionless magnetized plasma interaction in the context of astrophysical experiments

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(cosmic rays). Widely discussed mechanisms involve collisionless shocks in supernovae remnants (SNRs), micro-quasars, Gamma-ray bursts (GRBs), pulsars, blazers, etc, as a powerful source of energy for this. The understanding of processes, leading to the formation of collisionless shocks, their structure, dependence on plasma parameters, i.e. flow velocity and magnetization, is a key question in modern astrophysics. Laboratory experiments aim to shed light on the formation of collisionless shocks. Thanks to currently available facilities, parameters corresponding to SNR flow expansion into the interstellar medium within the external (ambient) magnetic field, for example the magnetic field of the former star, may be achieved.
There are certain questions in the modelling of astrophysical collisionless shocks in laboratory conditions, one of the most important is the initialization of the shock. Experiments, conducted recently, which deals with the counter-streaming plasma-plasma flows interaction, shows the increasing of electron density in the interpenetration region in the presence of an ambient magnetic field compared to the unmagnetized flows. The theoretical studies, including numerical simulations are performed to understand the experimental results. We show the highly nonlinear behaviour of plasma, due to the presence of the magnetic field. Several models are presented and analyzed to understand the present and possible future experiments.

Astrophysically relevant electromagnetic plasma instabilities in high-power laser generated counter-streaming plasma flows

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Astrophysical collisionless shocks are ubiquitous, occurring in supernova remnants, gamma ray bursts, and protostellar jets. They occur when the ion-ion collision mean free path is much larger than the system size [Ryutov, PPCF, 2012]. High power laser experiments are ideal to study microphysics questions relevant to this system on shock formation mechanism; magnetic field generation; and particle acceleration [Park, HEDP, 2012.] Many experiments have been performed on the Omega and Omega-EP laser facilities. High velocity plasmas are created by using two high intensity laser pulses to irradiate two CH2 disks faced each other. The electric and magnetic fields in the counter-streaming plasmas were imaged with proton probes. We have observed spectacular self-organizing, large, stable field structure that arise in counter-streaming interpenetrating supersonic plasma flows in the laboratory. [Kugland, Nature, 2013]. The double flow experiment show unexpected high increase in Te and Ti that are accounted from intra collisional processes and electrostatic instabilities [Ross, PRL, 2013.] Our recent DHe3 probe experiment shows filamentary structures of Weibel instabilities. This paper will present the experimental results, simulation results and the theoretical understandings of these observations from Omega and the planned NIF experiments where we will observe the fully formed shocks.

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Particle simulation of photoionization by high power laser

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In this work, molecular dynamics (MD) particle simulation is combined with atomic kinetics described by a collisional-radiative (CR) model. The physical processes, such as photoionization and Auger process, are simulated during the interaction of X-ray free-electron laser with solid Fe targets. The simulation shows similar results as recent experiments at X-ray intensities up to 10^20 Watts/cm2, which may be the brightest X-ray beam in the entire Universe. MD+CR simulation offers a new approach to understand such high power laser interaction with matter.

New regimes of solid-state plastic flow at extreme conditions for laboratory astrophysics

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I will describe new regimes of solid-state plastic flow at extreme conditions for HED laboratory astrophysics. These results are relevant to hypervelocity impacts, space hardware durability, and planetary giant impacts that can affect planetary interiors and planetary formation dynamics. We use high power lasers to study the Rayleigh-Taylor and Richtmyer-Meshkov instability in the solid state plastic flow regime on the Janus, Omega, and NIF lasers. [Park 2010, 2014; Rudd 2010] We also are developing dynamic diffraction to understand the lattice level dynamics and plastic relaxation directly behind the shock. [Comley 2013; Wehrenberg 2014] A sophisticated multiscale model of this plasticity has been developed and compared with our experimental results. [Barton 2011] The conclusions from these comparisons of theory with experiment are interesting and in some cases quite surprising. Long-held tenets of plasticity in BCC metals are being challenged in these high pressure, high strain rate experiments. [Rudd 2012, 2014; Remington 2012] Highlights from these experiments will be given, and connections to planetary and space settings will be described. [Kraus 2012; 2014]

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LMJ/PETAL Laser Facility: overview and status

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The advent of high-power lasers facilities such as NIF, and Laser Megajoule (LMJ) in the near future opens a new era in the field of High Energy Density Laboratory Astrophysics. The LMJ, keystone of the French Simulation Program, is under construction at CEA/CESTA and will deliver 1.3 MJ with 176 beam lines [1]. The first physics experiments on LMJ will be performed at the end of 2014 with 2 quadruplets (8 beams). The operational capabilities (number of beams and plasma diagnostics) will increase gradually during the following years. I will describe the current status of the LMJ facility and the first set of x-ray diagnostics to be used during the commissioning phase and the first experiments. The PETAL project [2], part of the CEA opening policy and financed by the Conseil Régional d'Aquitaine, the French ministry of Research and the European Union, consists in the addition of one short-pulse (500 fs to 10 ps) ultra-high-power, high-energy beam (a few kJ compressed energy) to the LMJ facility. PETAL will offer a combination of a very high intensity multi-petawatt beam, synchronized with the nanosecond beams of the LMJ. PETAL will extend the LMJ diagnostic capabilities and will be devoted to academic research. Specific diagnostics adapted to PETAL capacities are being fabricated in order to characterize particles and radiation yields that can be created by PETAL. A first set [3] will measure the particles (protons/ions/electrons) spectrum (0.1 to 200 MeV range) and will also provide point projection proton-radiography. LMJ/PETAL like LIL will be open to the academic community. Laboratory astrophysics experiments have already been performed on the LIL facility. The academic access to LMJ/PETAL and the selection of the first proposals will be done by Institut Laser Plasma (ILP) through the PETAL international Scientific Advisory Committee.

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POSTER PRESENTATIONS

Russian Megagrant Project on Laboratory Astrophysics Eugeny DERISHEV/Alexander SOLOVIEV	P1
Multiphase Equation of State of Iron near the Earth Core Conditions Olivier HEUZÉ	P2
High Energy Density Radiative Transfer Benchmark Solutions via Heterogeneous Computing Daniel HOLLADAY	P3
Fully Implicit Filtered PN for High-Energy Density Thermal Radiation Transport using Linear Discontinuous Galerkin Finite Elements Vincent LABOURE	P4
Electromagnetic fluctuations in relativistic plasmas and application to laser-induced collisionless shocks Charles RUYER	P5
Sun-like Magnetic Turbulence with a Table-Top Intense Laser Gourab CHATTERJEE	P6
Multicomponent Reynolds-Averaged Navier–Stokes Simulations of Reshocked Richtmyer–Meshkov Instability and Turbulent Mixing Experiments: Large Mach and Atwood Number Effects J. Tiberius MORAN-LOPEZ/Oleg SCHILLING	P7
New equation of state of fluid Helium from the atomic to the fully ionized phase François SOUBIRAN	P8
Optical diagnostic of interactions of laser-produced plasma outflows Yutong LI	P9
Non-standard paradigm of Cosmic Rays diffusion Mikhail MEDVEDEV	P10
Stabilization of Rayleigh Taylor instability by strong coupling effects in Inertial Confinement Fusion targets Amita DAS/Predhiman KAW	P11
Radiative Shock Solutions using Multi-group Discrete-Ordinates Transport Jim FERGUSON/A. Miguel HOLGADO	P12
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Spectral properties of buried-layer targets heated by fast electrons Vincent DERVIEUX	P14
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Poster P1

Russian Megagrant Project on Laboratory Astrophysics

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Poster

The talk is concerned with new project on laboratory investigation of extreme astrophysical objects using high-power laser and m icrowave radiation sources. The project will be implemented on the basis of Institute of Applied Physics of Russian Academy of Science (IAP RAS, Nizhniy Novgorod, Russia). The financial support is carried out by the Ministry of education and science of the Russian Federation. The scientific coordination of the project will be provided by Prof. Julien Fuchs (LULI, Ecole Polytechnique, France).

New laboratory will be equipped with a unique petawatt femtosecond laser system PEARL, the most powerful in Russia, as well as a range of high-power microwave sources (gyrotrons) produced by IAP RAS, strong magnetic field sources and the newest diagnostic systems. The main goals, anticipated results and scientific approaches of the project will be discussed.

Poster P2

Multiphase Equation of State of Iron near the Earth Core Conditions

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Poster

Very recent experimental results have improved our knowledge about the thermodynamic properties of iron beyond 150 GPa (see Amadou, Anzellini, Morard, Ping and Wang, 2013). Moreover the recent discovery of many exoplanets has provided a large amount of data and information about the density/radius relationship in planets (see Swift 2012) where iron plays an important role. At the same time, we have developped a complete multiphase equation of state (see Heuzé 2012) in a S(V,E) flexible form which allows use, combination and comparison of different models for any material.

These improvements led us to propose a complete multiphase equation of state for iron up to about 400 GPa and 7000 K.

The phase transition according to Hugoniot experiments or isentropic assumption correspond to different volume and entropy jumps which are linked by the equation of state parameters. The core conditions cannot be deduced only from pure iron properties. They also depend on the mantle boundary condition, the validity of the isentropic assumption, and the real composition of the core. Then the quantitative knowledge of the sensitivity to equation of state parameters is necessary for the joint progress of matter and planetary sciences.

We will mainly focus our study around the solid/liquid phase transition near the Earth core conditions, and the sensitivity of the jumps and the parameters to their uncertainties.

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Poster P3

High Energy Density Radiative Transfer Benchmark Solutions via Heterogeneous Computing

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Poster

High energy density radiative transfer benchmark solutions are presented for 1-D slab, cylindrical, and spherical geometries using a three-temperature (electron, ion, and radiation) model. A transport model is used for the radiation, a conduction model is used for the electrons, and ion motion is assumed negligible. These benchmarks are useful in the veri- fication and testing of simulation codes for laboratory astrophysics as well as high-energy density physics. The solutions require linearization of the coupled equations and are obtained via specific cubic functional forms (in temperatures) for the heat capacities and electron-ion coupling factor. Com- parisons to existing radiative transfer codes are presented. These solutions are semi-analytic in that their exact forms can be written down, but 2-D integrals must be computed numerically for each point in space and time. These integrals are slowly convergent and so a numerical integration rou- tine was developed in OpenCL to take advantage of the high throughput that heterogeneous computing offers. Although capable of running on any OpenCL device, the nature of numerical integration meant GPUs were an excellent choice.

Poster P4

Fully Implicit Filtered PN for High-Energy Density Thermal Radiation Transport using Linear Discontinuous Galerkin Finite Elements

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Poster

The solution of thermal radiation transport as part of radiation-hydrodynamics calculations is important in the simulation of astrophysical phenomenon as well as high-energy density physics applications such as inertial confinement fusion. In this work we present an implicit method for solving the spherical harmonics (PN) equations of radiation transport using filtered expansions. Since the introduction of such filtered PN methods by McClarren and Hauck, these approaches have been successful in producing high fidelity solutions to difficult transport problems. Nevertheless, there has been almost no investigation of the how to robustly and efficiently solve these equations implicitly in time - implicit integration is necessary unless one wants to evolve the flow at the speed of light time scale. Implicit solvers also impact the choice of filter strength. In this paper we present results of implicit filtered PN radiation transport simulations and discuss preconditioning strategies as well as the effect of implicit time integration on the necessary filter strength. We compare the results to reference Monte-Carlo calculations for several standard test problems, including radiation transport in a laser-driven shock tube experiment.

Poster P5

Electromagnetic fluctuations in relativistic plasmas and application to laser-induced collisionless shocks

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Poster

The interaction of high-energy, ultra-high intensity lasers with dense plasmas is known to produce copious amounts of suprathermal particles. Their acceleration and subsequent transport trigger a variety of Weibel-like electromagnetic instabilities, acting as additional sources of slowing down and scattering. Their understanding is important for the many applications based upon the energy deposition and/or field generation of laser-driven particles [1,2]. Recently, the apparent similarity of these mechanisms with those expected in colliding astrophysical flows has motivated to investigate the generation of self-magnetized, collisionless shocks by means of intense lasers [3,4]. Beside the scientific interest of this topic, a goal is to design an experimental testbed for describing the turbulence generation and, on a longer term, the particle acceleration, occurring in powerful astrophysical objects (e.g., gamma-ray bursts, supernova remnants, etc.) [5,6].
In a first part of this presentation, we study the pulsation-wavevector-resolved electromagnetic thermal spectrum sustained by a drifting relativistic plasma. In particular, we present analytical formulae for the magnetic spectra, the latter serving as seeds for growing magnetic modes in counterstreaming plasmas [7]. This allows us to estimate the saturation time of the Weibel instability of relativistic pair plasmas. Our predictions are shown to match 2-D particle-in-cell (PIC) simulations over a three-decade range in flow energy [8].
In a second part, we address the electromagnetic instabilities developing in laser-irradiated overdense plasmas using both linear theory and PIC simulations (Fig. 1). In contrast to the standard astrophysical scenario that relies upon the buildup of an ion-ion instability, we demonstrate that the early-time magnetic turbulence generated by the suprathermal electrons is strong enough to isotropize the ions. Estimates of the shock formation time and threshold laser energy are obtained in terms of the laser intensity and plasma composition. Correct agreement is found with PIC simulation results [9].

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Poster P6

Sun-like Magnetic Turbulence with a Table-Top Intense Laser

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Poster

Turbulence is ubiquitous, manifesting itself on both terrestrial and galactic scales, turbulent flows abounding in magnetized plasmas such as the interstellar medium, the solar wind and the magnetosheath of planetary magnetospheres [1, 2]. However diverse the origin and manifestation, turbulence is often characterized by a power-law scaling in the Fourier energy spectrum in the so-called “inertial range”, independent of the mechanisms of energy injection as well as dissipation.

We report results from recent experiments, where we probe the megagauss magnetic fields generated in intense laser-solid interactions at irradiances of ~10^18 W/cm^2 at near-solid densities of ~ 10^22 /cm^3. At initial time-scales, the energy spectrum shows the famous Kolmogorov -5/3 scaling [3] in the k-spectra, whereas ~20 ps after the incidence of the main interaction laser pulse, the k-spectrum shows two distinct power-law scalings, separated by a spectral ‘kink', which becomes progressively more prominent at longer time-scales (up to ~ 75 ps). Similar spectral kinks have been observed previously in solar flare loops [4] as well as in spacecraft observations of the solar wind [5, 6]. In light of the ubiquity of turbulence, our results seem even more fascinating as they portray dynamic turbulent mechanisms in highly non-equilibrium regimes, providing an experimental test-bed for turbulent mechanisms of astrophysical significance, which can be tailored and simulated in a laboratory with a table-top laser.

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Poster P7

Multicomponent Reynolds-Averaged Navier–Stokes Simulations of Reshocked Richtmyer–Meshkov Instability and Turbulent Mixing Experiments: Large Mach and Atwood Number Effects

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Poster

Reshocked Richtmyer–Meshkov turbulent mixing of gases with various large shock Mach numbers from experiments previously performed in the horizontal double diaphragm shock tube at the University of Provence is simulated using a third-order weighted essentially nonoscillatory implementation of a new K–\epsilon multicomponent Reynolds-averaged Navier–Stokes model. The following gas combinations are considered, as summarized in Valerio et al. [Phys. Fluids 11, 214 (1999)]: CO_2/He, CO_2/Ar, and CO_2/Kr (with At = -0.73, -0.05, and 0.3, respectively) and incident shock Mach numbers Ma = 2.4, 3.1, and 4.5 for each gas pair. The evolution of the mixing layer widths is shown to be in good agreement with the experimental data. Budgets of the turbulent transport equations are used to elucidate the mechanisms contributing to turbulent mixing in large Mach number reshocked Richtmyer–Meshkov instability. These results are contrasted with those from previous modeling of smaller Mach number experiments by Morán-López and Schilling [High Energy Density Phys. 9, 112 (2013); Shock Waves 24 (2014)] to identify the physical effects which require accurate modeling, including mean and turbulent enthalpy diffusion, pressure–dilatation, and dilatation dissipation. Implications of this study for modeling turbulent mixing in astrophysical flows are discussed.

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Poster P8

New equation of state of fluid Helium from the atomic to the fully ionized phase

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Poster

Helium is the second most abundant chemical element in the universe. It can be found in its atomic phase in the interstellar medium and protostellar clouds but is thermally ionized in stars and pressure ionized in giant planets or compact objects such as white dwarfs or neutron stars. The corresponding physical properties highly depend on which phase is relevant. Therefore, the need for a reliable equation of state (EOS) covering this wide range of parameters has continuously grown in the past two decades. Indeed, giant planet modeling needs accurate data from the atomic phase at 1 atmosphere up to the partially ionized plasma in the inner envelope (up to 10 TPa). Stellar models explore the same range of densities but at much higher temperatures (up to 10^8 K) with a much weaker Coulomb coupling in the system.

In the past two decades many improvements have been performed in theoretical studies of Helium and in numerical simulations. They provided us with reliable data but scattered over very different ranges of parameters. We will show that it is possible to link them all together within a single framework, namely a new fitted analytical model for fluid Helium ranging from 10^-4 g/cc up to 100 g/cc and from 100 K up to 10^9 K in the density-temperature plane.

We will also compare this EOS with experimental data now available thanks to shock compression experiments and give new predictions for upcoming high energy density experiments.

Poster P9

Optical diagnostic of interactions of laser-produced plasma outflows

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Poster

Plasma outflows or jets exist widely in universe. Plenty of astrophysical processes, like magnetic reconnection, shock waves, etc, are produced in the interactions of outflows. Those models have been used to explain many observed phenomena, such as solar flares, high energy comic ray generation. In this talk, we will present our recent experimental studies of interactions between two laser-produced plasma outflows at Shenguang II laser facility, which can delivery energy up to 2 kJ. Using optical interferometry and shadwography, we have observed the generation of shock waves and filaments for the low-density counter-propagating plasmas. While for two high-density plasmas jets propagating perpendicular to each other, we have observed large angle deflection of the jets.

Poster P10

Non-standard paradigm of Cosmic Rays diffusion

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Poster

We revisit the current paradigm of Cosmic Ray (CR) propagation in turbulent magnetized interstellar and interplanetary media. We show that transport of CRs in the medium with the mean field gradient is described by anisotropic diffusion. This is illustrated with a toy 1D Markov chain model of a random walk with unequal probabilities. The model can be solved analytically and the result is: CR density distribution is markedly different from the standard diffusion, which is known to build a linear gradient of the density. We also briefly discuss how the difference of the diffusion coefficient for positively and negatively charged species may affect their spatial distribution. We discuss implications of these results.

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Poster P11

Stabilization of Rayleigh Taylor instability by strong coupling effects in Inertial Confinement Fusion targets

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Poster

It is shown that the viscoelasticity of a strongly coupled plasma medium due to strong inter-particle correlations leads to a suppression of the Rayliegh Taylor instability unless certain threshold conditions are met. The relevance of these results to experiments on laser compression of matter to high densities including those related to inertial confinement fusion using lasers has also been shown.

Poster P12

Radiative Shock Solutions using Multi-group Discrete-Ordinates Transport

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Poster

We present semi-analytic planar radiative shock solutions using a multi-group (MG) discrete-ordinates (Sn) radiation transport model. MG frequency integration is used to capture the frequency dependence of the material cross sections and the radiation intensity, and Sn radiation transport is used to capture the angular dependence of the radiation field. Comparisons are made with the grey-Sn radiative shock solutions of Ferguson, Morel, and Lowrie. Our solutions can be used to verify radiation-hydrodynamics codes. We apply a MG frequency integration to the O(u/c) steady-state frequency-dependent Sn radiation transport equation to determine the effect of frequency dependence on radiative-shock profiles. We consider several frequency-dependent cross sections.

Poster P13

Laser-driven ion accelerator for novel radiation source

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Poster

By using multidimensional particle-in-cell simulations, we study the electromagnetic emission from radiation pressure acceleration of ultrathin mass-limited foils[1]. When a circularly polarized laser pulse irradiates the foil, the laser radiation pressure pushes the foil forward as a whole. The outer wings of the pulse continue to propagate and act as a natural undulator. Electrons move together with ions longitudinally but oscillate around the latter transversely, forming a self-organized helical electron bunch[2]. When the electron oscillation frequency coincides with the laser frequency as witnessed by the electron, betatronlike resonance occurs[3,4]. The emitted x rays by the resonant electrons have high brightness, short durations, and broad band ranges which may have diverse applications[5].

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Poster P14

Spectral properties of buried-layer targets heated by fast electrons

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Poster

In the past few years, several experiments [1, 2, 3] using Ultra High Intensity lasers (1017 - 1019 W/cm-2) have demonstrated the possibility to heat a layer of material to very high temperatures (hundreds of eV) with densities close to solid. It is of particular interest to study these plasma conditions to constrain theoretical models of dense plasma equations of state or radiative opacities. To achieve this goal plasma conditions (temperature, density, LTE/NLTE) have to be well characterized.

Preliminary results of experiments performed on ELFIE laser facility at LULI Laboratory will be presented. In these experiments, we measured K-shell emission of a well-known material such as aluminium to infer the expected range of temperatures. Time-integrated spectra were recorded from the front (laser) side of the target by using a Von-Hamos spectrometer, alike time-resolved spectra were measured from the rear side by using a X-ray streak picosecond camera coupled to a spectrometer. Different targets as well as laser conditions have been tested to infer effects on the heating process.

Simulations obtained from PIC, hydro-rad and atomic codes will be presented. Experimental data coupled with these simulations illustrate the capability to limit hydrodynamic expansion by using buried-layer targets. Heating a high-density sample is achievable: Te>200 eV and ρ>1.5 g/cc were reached with 2J of laser energy. Moreover, time-resolved diagnostics could allow measurements of LTE and homogeneously heated plasmas under certain conditions.

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Poster P15

Numerical Analysis of Hydrodynamic Instability in Magnetized Laser Ablation Flow

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Poster

We have conducted Radiation Magneto-Hydrodynamics (RMHD) simulations of Richtmyer-Meshkov Instability in a magnetized counter flow produced by intense lasers. A jet-like plasma from a planar plastic target is formed by local heating, and parallelly located another target is ablated by the radiation from the plasma, reproducing past experimental works. The magnetic field is amplified up to ~40 times greater than the background value at the interface at which the instability occurs. However, a certain extent of the amplification results from the compression effect induced by the counter flow, and the obtained amplification level is difficult to be measured in the experiments. An experiment for observing a clear amplification must be designed through the RMHD simulations.

Poster P16

Analytico-numerical Study of the Vishniac instability in supernova remnants

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Poster

The Vishniac instability (V.I.), analytically conceptualized by Vishniac (Vishniac 1983, Ryu & Vishniac 1987) and frequently invoked in order to explain the complex structure of supernova remnants (SNR), is not well understood yet. Moreover, the SNR observations show that SNR have undergone instabilities, but the act of the V.I. is not clearly proved. There are some strong assumptions and contradictions in the analytical work. Up to now, the HED experiments have not concluded on the existence or not of the V.I. (Grun et al. 1991, Edens et al. 2010).

Using a model considering an infinitely thin shell, we have calculated dispersion relations in the same way than Vishniac (Vishniac 1983), with less artificial constraints. We have found that the growth rate is in a more general case lower than Vishniac's predictions.

In addition, we have also run 2D numerical simulations with the HADES code in order to better understand the dynamics of the V.I. First, we will detail the evolution of the instability triggered by the introduction of a spatial perturbation in the SNR in Sedov phase. We explain the processes leading to the final aspect of the SNR in simulations. Nevertheless, we will show that the instability is always vanished, can be seen by the attenuation of the shock front perturbation, confirming previous results (Cavet et al. 2009, Michaut et al. 2012). Second, we have studied cooled SNR by adding a cooling function term in the equations. Actually, after the Sedov phase the SNR enters in a radiative phase, leading to a thin shell behind the shock front. We have investigated if the thickness of the shell has an influence on the growth rate, as suggested by analytical studies. We will compare numerical and analytical results. In spite of these efforts to mimic the reality, we will demonstrate that the shock front becomes always spherical (without fragmentation) but presents large instability tracks.

Poster P17

Production of petawatt laser pulses of picosecond duration via Brillouin amplification of nanosecond laser beams

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Poster

Previous studies have shown that Raman amplification in plasma is a potential route for the production of petawatt pulses of picosecond duration at 351 nm [Trines et al., Phys. Rev. Lett. 107, 105002 (2011)]. Laser pulses with these parameters are invaluable for High Energy Density Laboratory Astrophysics experiments. In this paper we show, through analytic theory and multi-dimensional particle-in-cell simulations, that such pulses can also be obtained through Brillouin amplification of a short seed laser beam off a long pump beam at moderate intensity. We have identified a narrow but well-defined parameter regime where we achieve pump-to-probe compression ratios of up to 100 and peak laser fluences over 1 kJ/cm^2 with 50% efficiency. Scaling laws governing the optimal parameter space for pump beam, seed beam and plasma will be derived using a self-similar model for Brillouin scattering, and verified via simulations. A comparison with Raman amplification will be made, to determine which scheme is most suitable for which purpose.

Poster P18

Relativistic plasma astrophysics with intense lasers

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Poster

Recent progresses of laser technologies enable us to investigate space and astrophysical phenomena in laboratories. In space plasmas the local observations by spacecrafts provide us the microscopic information of the plasma and electric/magnetic fields, however, it is difficult to obtain the global structures of the phenomena. In astrophysical plasmas, in contrast, global images provide us the macroscopic information, although there is no local observation and thus no microscopic information. Laboratory experiments on space and astrophysical phenomena provide us the local and global information simultaneously. With this unique capability we have investigated plasma jets, collisionless shocks, generation and amplification of a magnetic field, magnetic reconnections, and particle acceleration in the Universe. So far, most of them are limited to non-relativistic regime. While the space plasmas are mostly non-relativistic, the astrophysical plasmas can be highly relativistic. Thus, the laboratory astrophysics with intense lasers, relativistic laboratory astrophysics, provides us unique opportunities to investigate relativistic phenomena in the Universe. We establish a platform to investigate space and astrophysical phenomena from non-relativistic to relativistic regime with the 100 TW laser facility, with its stable operation, high-repetition rate, and flexible beam lines. We model astrophysical phenomena in laboratory, and investigate the physical processes never accessible by astrophysical observations.

Poster P19

Nucleosynthesis at the deep potential well of nanosecond vacuum discharge as imitation of gravity in stars

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Poster

DD neutrons from microfusion at the interelectrode space of a table-top low energy nanosecond vacuum discharge (NVD) with deuterium-loaded Pd anode has been demonstrated earlier [1]. The detailed particle-in-cell (PIC) simulation of the discharge experimental conditions have been developed using a fully electrodynamic code KARAT [2]. The principal role of a virtual cathode (VC) and the corresponding deep potential well (PW) formed in the interelectrode space are recognised. PIC modeling allowed to identify the scheme of small-scale experiment [1,2] with a rather old branch of plasma physics as inertial electrostatic confinement fusion (IECF) (see [2-5] and refs therein). The calculated depth of the quasistationary potential well (PW) of the VC is about 60 kV. Deuterons being trapped by this well are accelerating up to the energies of few tens keV that provides DD nuclear synthesis under head-on collisions (experimental data and modelling results related are presented at [6]). Meanwhile, any ions of other elements like He, C, O, Si being placed at PW (even with low charges Z) have to be accelerated easily up to the head-on collisions energies which are corresponding to the temperatures of ignition Tign for different shells of stars (remind, that the energy of ions at the depth of PW will be ~ Z). At the experiment with NVD we are recognising the appearing and accumulating of C, O, Na, Mg, Al, Si, S, Cl, K, Ca, and we are able to differ them from any possible impurities at vacuum discharge. The characteristic X-rays radiation from anode surface is recognizing especially strong lines of Si an S during component analysis. Beyond of other elements, the cathode surface contains Fe and Mn. The interesting experimental fact also that the relation of their concentrations is Mn/Fe > 1 at any cathode area (cathode itself represents in whole something like the diagnostic tool or container for products of nuclear burning at the deep PW). This relation Mn/Fe > 1 would be explained by capture of DD neutrons by irons Fe(n,p)Mn along the big number of discharge shots. The review of experimental data accumulated as well as corresponding PIC modeling of the processes of nuclear burning at the potential well of vacuum discharge (including advanced fuel like p- B11) will be presented.

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Poster P20

Bremsstrahlung X-rays from high energy density plasmas and hot electron temperature

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Poster

Characteristics of Bremsstrahlung X-rays emitting from a plasma can give an information about the electrons of the plasma from which those X-rays are generated. Thus the measurement of those continuous X-ray spectrum is important in such studies as ignition mechanisms of nuclear fusion, equation of state, opacity, phenomena of extreme conditions, stellar plasmas, and so on.

Bremsstrahlung cannon (BC) detector which is made of several kinds of metal filters such as Al, Ti, Fe, Cu, Sn, Ag, Ta, Au, Pb etc in series, which have different X-ray transmission coefficients, is used to measure those X-rays since it can record the different responses on the sensors (imaging plates) placed behind each of those filters, depending on the X-ray energy spectrum.

In this presentation, methods and results of the analysis of the experimental data which were obtained at Petawatt laser facility in Gwangju will be given as well as comparison with data obtained from electron spectrometers and/or MULTI hydrodynamic simulation, to give an idea about the hot electron temperature in the laser produced plasma.

Poster P21

Richtmyer-Meshkov mode coupling under steady shock conditions in the high-energy-density regime

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Poster

The Richtmyer-Meshkov (RM) process occurs when a shock wave crosses an interface between two materials of different densities and deposits vorticity on it due to interface and/or shock-front structure, causing this initial structure to grow in time. This process occurs when astrophysical shock waves cross density gradients. It has been suggested, for example, that RM is responsible for observed structure in the Tycho supernova remnant.

Recent advances in pulsed-laser technology permit the creation of laser conditions not previously feasible, which in turn offers the opportunity to probe high-energy-density (HED) hydrodynamics, relevant to the aforementioned phenomena, under new conditions. In this talk, we will present the results of an experiment that takes advantage of the capability of the OMEGA-EP laser to probe aspects of the RM process under steady shock conditions, and arising from a well-characterized, multimode initial seed perturbation. These conditions permit the first observation of the interaction of modes, along with their growth and saturation, in the HED regime.

Poster P22

PIC Simulations of Relativistic Shear Flows and Applications to Blazars and GRBs

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Poster

This paper summarizes recent results obtained from 2 -and -3 D particle-in-cell (PIC) simulations of relativistic shear boundary layers (SBL). In addition to the creation of sustained, ordered magnetic fields, we find efficient energization of nonthermal electrons to high energies, making the SBL a strong candidate for enhanced synchrotron emission in relativistic jets, from blazars to gamma-ray bursts. The case of the hybrid electron-positron-ion shear flows is particularly interesting as it leads to the formation of an electron spectrum with both a high-energy peak near the ion kinetic energy, plus a hard power-law tail of slope near - 3. The electron momentum distribution exhibits extreme anisotropy, making the SBL a strong candidate for enhanced emission of synchrotron-self-Compton (SSC) radiation in some cases.

Poster P23

Magnetic field generation and amplification in an expanding plasma

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Poster

Particle-in-cell simulations are used to investigate the formation of magnetic fields, B, in plasmas with perpendicular electron density and temperature gradients. For system sizes, L, comparable to the ion skin depth, di , it is shown that B □ di /L, consistent with the Biermann battery effect. However, for large L/di , it is found that the Weibel instability (due to electron temperature anisotropy) supersedes the Biermann battery as the main producer of B. The Weibel-produced fields saturate at a finite amplitude (plasma $\beta \approx 100$), independent of L. The magnetic energy spectra below the electron Larmor radius scale are well fitted by power law with slope −16/3, as predicted in Schekochihin et al., Astrophys. J. Suppl. Ser. 182, 310 (2009).

Poster P24

High energy proton generation by radiation pressure acceleration with petawatt laser pulses

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Poster

Proton/ion acceleration obtained through superintense laser-plasma interaction has attracted strong interests over last ten years. Energetic protons and ions have strong prospects for such applications as hadron therapy, inertial confinement fusion, laboratory astro-physics and nuclear/particle physics [1, 2]. Laser driven proton/ion accelerators using ultra-high power lasers could be one of prospective candidates for compact and cost-effective cancer therapy [3]. Laser-driven proton/ion beams, compared to conventional accelerators, have outstanding features such as low emittance, small source size of a few μm, ultra-short duration of picoseconds and huge acceleration gradient of ~1 MeVμm−1. Although laser-driven proton/ion acceleration has significant merits for unique applications, there exist numerous issues to overcome, such as attainable maximum energy, spectral and angular control, conversion efficiency, energy stability and repetition rate. Still the biggest challenge is the achievement of several hundred MeV protons suitable for hadron oncology.

We report proton/ion acceleration from ultrathin polymer targets by irradiating linearly polarized (LP), 30-fs, 1-PW Ti:sapphire laser at Center for Relativistic Laser Science. The laser intensity applied was from 5×10^19 W/cm^2 to 3.3×10^20 W/cm^2, and the target thinkness was from 10 nm to 100 nm. A maximum proton energy of 45 MeV was reached when a 10-nm-thick target was irradiated at the laser intensity of 3.3×10^20 W/cm^2. The transition of proton energy scaling from I1/2 to I with respect to laser intensity I was observed as a consequence of the hybrid acceleration mechanism including target normal sheath acceleration, radiation pressure acceleration, and Coulomb explosion assisted-free expansion [4].

Recently we have succeeded in obtaining 80 MeV protons from ultrathin polymer target using circularly polarized (CP) laser pulses with intensity of 6.1×10^20 W/cm^2. This result is one of the highest value obtained with a short pulse (30 fs) high-repetition rate (0.1 Hz) Ti:sapphire laser. In experiments we achieved a maximum proton energy of 80 MeV and the energy scaling was quadratic, E_max ~ I^2. This result clearly coincides with the scaling feature of the light-sail radiation pressure acceleration (LS-RPA) mechanism [5]. On the other hand the maximum proton energy obtained with LP laser pulses was 58 MeV with a linear scaling. This result confirms the LS-RPA mechanism that the proton acceleration by CP laser pulses is more efficient than that by LP laser pulses.

Poster P25

Quantum nuclear effects on the compressed ice and hydrogen

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Poster

Ice and hydrogen are both key elements in giant planets. Understanding their structures and dynamical properties such as transport behaviors are crucial in astrophysics. However, quantum nuclear effects (NQEs), especially for H, are usually neglected. We performed Ab initio path integral molecular dynamics to study the dynamics of high-pressure and high-temperature behaviors of ice and liquid hydrogen.

Firstly, we investigated the temperature-induced phase transition and oxygen K-edge x-ray absorption spectra of ice VII, VIII and X using ab initio path-integral molecular dynamics simulations. The tremendous difference between experiments and the previous theoretical predictions is closed for the phase diagram of ice below 300 K at pressures up to 110 GPa. Proton tunneling assists the proton-ordered ice VIII to transform into proton-disordered ice VII where only thermal activated proton-transfer cannot occur. The oxygen K edge with its shift is sensitive to the order-disorder transition, and therefore can be applied to diagnose the dynamics of ice structures. (Scientific Reports, 3: 3272)

Secondly, the transport properties of dense liquid hydrogen are studied. It is well known that scattering or collision is the key physics in determining the transport properties of electrons and ions. Quantum tunneling is a typical character in quantum physics, and is generally regarded to exist at low temperatures (T) for ions in condensed matter. Here we investigate the nuclear quantum effects (NQEs) on the transport properties of dense liquid hydrogen up to T=1 eV using ab initio path-integral molecular dynamics simulations. With the inclusion of NQEs, ionic diffusions are strongly enhanced by the magnitude from 100% to 15% with increasing temperature at 10 g/cm3, while electrical and thermal conductivities are heavily suppressed. In particular when T=1 eV, where the NQEs have little effects on the static structures, the diffusion is still much larger than that without NQEs. The occurrence of this striking effect of NQEs on transport behaviors updates the perspective on the dynamics of dense liquid hydrogen at high temperatures.

Poster P26

Simulations of the kinetics and radiative properties of blast waves launched in clusters of xenon

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Poster

Radiative shock waves are ubiquitous throughout the universe and play a crucial role in the transport of energy into the interstellar medium. This fact has led to many efforts to scale the astrophysical phenomena to accessible conditions. In some laboratory experiments radiative blast waves are launched in clusters of gases by means of the direct deposition of the laser energy. In this work, by using a collisional-radiative model, we perform an analysis of the kinetics and the radiative properties of a blast wave launched in a xenon cluster according to the method commented above. In particular, for both the shocked and unshocked material, we study the influence of different effects such as LTE, steady-state or time-dependent NLTE simulations, plasma self-absorption or external radiation field in the determination of those properties and also in the diagnosis of the electron temperature of the blast wave.

Poster P27

Dynamic control of laser-radiation-pressure-driven proton beams by moving focusing electric-fields in a cone-mass-limited target

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Poster

Dynamic control of laser-radiation-pressure-driven proton beams can be realized by using a guiding cone in which the foil is embedded. The oscillating electric-field of focused circularly polarized laser pulse with transverse Gaussian profile pulled out electrons from the cone walls, which leads to a strong sheath field within the cone. Co-moving with the accelerated foil, this sheath field tends to persistently focus the accelerated proton bunch and effectively suppresses undesirable transverse explosion. At laser intensity of ~2.74×1022W/cm2,a highly quasi-monoenergetic proton beam with a peak energy of 1GeV/u, an energy spread <6%, and a divergency angle <3° is obtained.

Poster P28

Heterogeneous Interactions in HH Objects: Observations, Simulations, and Experiments

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Poster

Herbig-Haro (HH) jets are understood as heterogeneous beams of plasma traveling at supersonic velocities. Structures within jet beams are thought to be caused by variations in the momentum at the jet source. This variability results in a “clumpy” jet flow leading to a variety of heterogeneous interactions. HST time-series observations of HH objects reveal localized bright knots in H-alpha and regions of strong [S II]. Some of these H-alpha features represent shock fronts caused by variable velocities, and the [S II] regions represent cooling regions behind shocks. We have explored the dynamics of such jets at high resolution using AMR methods in both 2.5-D and 3-D. Effects due to radiative cooling and magnetic fields play a crucial role in the evolution of these jets and have thus been included in the simulations. We produced synthetic emission maps of H-alpha and [S II] to compare with the observations. Controlled laboratory experiments have been conducted which explore issues related to the propagation of magnetized, radiatively cooling jets. The dimensionless numbers that determine the dynamics are similar in both the experiments and the astrophysical environment, therefore the results are scalable and comparable. The jets in these experiments show evidence of kink mode instabilities which fragment the jet into supersonic clumps. This is not the same mechanism by which our simulated jets exhibit a clumpy structure, but it is still appropriate to compare the interactions within the clumpy jet flow.
The HST observations also reveal that some of these H-alpha knots are brighter than expected, and these are located at the intersection points between separate bow shocks. When bow shocks intersect at an angle at or above a certain critical value, a third shock (Mach stem) will form. Mach stems form perpendicular to the direction of flow, so incoming plasma will encounter a planar shock instead of an oblique one, hence the brighter emission at this location. To study this particular feature of HH objects, we conducted a set of simulations of intersecting bow shocks in both 2-D and 3-D. We studied the effects of cooling on the formation of Mach stems from both stationary and moving bow shocks. The simulations of moving bow shocks show that a Mach stem can exist below the critical angle for a certain period of time. Experiments have also been conducted in order to understanding the formation, growth, and destruction of Mach stems in the warm, dense plasma regime. Experimental results indicate how the growth rate depends upon included angle.

Poster P29

Particle - in - Cell Simulation of Electron Beam through Plasma Medium

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Poster

The transport of energetic electron beam through plasma medium has been a topic of considerable interest in the context of fast ignition applications. The propagation of energetic beams in a plasma are typically riddled with beam plasma related instabilities, such as the Weibel and two stream instabilities. A two and a half dimensional particle – in- cell simulations have been carried out to understand the nonlinear regime of the instability. In particular results on the generation of intense magnetic fields in the nonlinear phase would be presented.

Poster P30

3D Structure and Properties of a Laser-Driven Laboratory Radiative Shocks

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Poster

Radiation may be a major component of the momentum and energy budgets of an astrophysical object. This is the case of accretion columns around Classical T Tauri stars, which, while impacting the stellar surface, form radiative shocks. Such shocks are believed to significantly contribute to the observed signature of these young stars. It is therefore crucial to understand the physics of such shocks.

One way to achieve this goal is to study experimentally this physical effect. Our group has been involved for several years in the laboratory generation of radiative shocks, by conducting, in particular, campaigns in PALS (Prague Asterix Laser System) facility. We propose to present the results of numerical simulations of a typical laser-driven shock generated in PALS. We will present 3D results of radiation hydrodynamic calculations performed by HERACLES code, and 3D results of gray and monochromatic radiative transfer post-processing obtained with IRIS code.

The work is supported by French ANR, under grant 08-BLAN-0263-07, and under grant ANR-11-IDEX-0004-02 (LABEX Plas@par project).

Poster P31

PHOTO-IONISATION OF GAS BY X-RAYS FROM A WIRE ARRAY Z-PINCH

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Poster

Photo-ionisation of gas by x-rays is a phenomenon of interest in astrophysics, where it can dominate impact ionisation. An experiment is presented in which the x-ray emission from a stagnated wire array z-pinch is used to photo-ionise gas inside a gas cell. Photo-ionisation studies with x-rays from wire array implosions on the Z facility at Sandia National Labs used a gas cell positioned side-on and at large distances from the pinch [1]. Due to the much smaller radiation power from a 1 MA z-pinch, in our experiments the gas cell is mounted in an end-on position, close to the pinch.

The experiment is conducted on MAGPIE (1.4 MA, 250 ns current pulse) imploding Al or W wire arrays. Radiation enters the gas cell through a window situated 10 mm above the top of the pinch. The window is transparent to photons above 300 eV. Gas composition and pressure are varied to observe different photo-ionisation regimes, in which the mean free path is on the order of, or larger than, the size of the system.

We study the dynamics of the photo-ionisation process in gas, and the dynamics of the plasma which is formed. Two-colour multi-time laser-interferometry, Schlieren imaging and optical spectroscopy will diagnose the plasma density and temperature. We present the results of preliminary experiments with this system.

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Poster P32

Simulation of nuclear astrophysical processes in plasma of relativistic laser pulse

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Poster

There is effective generation of gamma-radiation (with photon energies above 1 MeV), and acceleration of protons and heavier ions at energies up to 100 MeV per unit charge in the interaction of laser radiation with sub-picosecond duration plasma in a mode of relativistic intensities (10^18-10^20 W/cm^2). This complies with the basic requirements to the characteristics of the particle flows for the tasks of the nuclear laboratory astrophysics. Estimates conducted for some promising reactions show that proton-induced reaction 7^Li(p, n)7^Be and 9^Be(p, n)9^B are the most perspective for the tasks of the nuclear laboratory astrophysics from the point of view of obtaining directed flows of neutrons with energy less than 1 MeV. Optimization of the number and the energy spectrum of neutrons is possible dew to duration and intensity of the laser pulse.

The use of «long» laser pulses (up to 1 ps) increases not only the total number of high-energy particles, but also, in certain modes, the «temperature» of the forming spectrum. The contrast of the laser radiation is also important for the realization of the approach developed as use of a thin (less than 1 mkm) foil is necessary for improving mechanisms of protons and heavy ions acceleration. In general, the contrast of the laser radiation should be from 10^6 to 10^10 and more depending on characteristics of a stream of particles or quanta generated and intensity of the laser radiation used.

The experiments were performed on the Neodim 10 TW picosecond laser setup. The parameters of the laser pulse are as follows: energy, up to 10 J, wavelength, 1,055 μm; and duration, 1,5 ps. The focusing system based on the off-axis parabolic mirror with a focal length of 20 cm concentrates no less than 40 % of the laser-beam energy to a spot with a diameter of 15 μm, so that the mean intensity on the target is 10^18 W/cm^2 and the peak intensity is 2×10^18 W/cm^2.

The laser radiation that is generated in the Neodim setup is characterized by the prepulses of two types (with picosecond and nanosecond durations). The first prepulse with a duration of 1,5 ps and a relative intensity of less than 10^–8 (relative to the main pulse) precedes the main pulse by 14 ns. The second prepulse is the pulse of the amplified spontaneous emission. The FWHM of the second prepulse is 4 ns and its intensity relative to the main pulse is less than 10–8.

For the analysis of the initiation of the (p, n) nuclear reactions, we choose the 7^Li(p, n)7^Be reaction with a threshold energy for protons of 1,88 MeV, the 63^Cu(p, n)63^Zn reaction with a threshold energy of 4,1MeV, and the 48^Ti(p, n)48^V reaction with a threshold energy of 5 MeV. When the laser radiation is focused on the front surface of the Al-foil target with a thickness of 10 μm, the beam of accelerated protons is generated on the back surface. The proton beam initiates the (p, n) nuclear reactions on the LiF, Cu, and Ti secondary activation targets. Neutrons are detected in the experiments with all types of secondary targets, which indicates the initiation of the above (p, n) reactions.

The irradiation of targets with high-power laser pulses leads to the generation of the femto- and picosecond laser plasma, which serves as the table-top pulsed microaccelerator or nuclear microreactor. We present the experimental results on the initiation of various (p, n) nuclear reactions in the picosecond laser plasma. At a laser intensity of 2×10^18 W/cm^2, the following (p, n) nuclear reactions can be initiated in the picosecond laser plasma: 7^Li(p, n)7^Be, 63^Cu(p, n)63^Zn, and 48^Ti(p, n)48^V with the proton threshold energies ranging from 1.88 to 5 MeV. For the measurement of the number of the initiated (p, n) nuclear reactions, we employ the method based on the detection of neutrons by the detectors with the 3^He counters. The measured yields of the (p, n) nuclear reactions range from 5×10^1 to 10^5 reactions per laser pulse.

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Poster P33

Mapping filamentary instabilities of astrophysical relevance in intense-laser-generated megagauss magnetic fields

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Poster

Intense laser-plasma interactions provide a novel and fascinating platform to simulate astrophysical scenarios [1]. A multitude of plasma instabilities, often of astrophysical significance, manifest in the megagauss magnetic fields generated when an intense laser pulse irradiates a solid. Here we present snapshots of these megagauss magnetic fields, capturing their picosecond-scale evolution with micron-precision and delineating the evolution of filamentary instability mechanisms such as the Wiebel instability. The Fourier spectrum of these megagauss magnetic fields shows a power-law behaviour for the magnetic energy, which is a tell-tale signature of magnetic turbulence [2].
Detailed particle-in-cell simulations have shown that the relativistic hot electron transport in a hot dense laser-generated plasma suffers from several instabilities including the Weibel instability [3], which leads to the spatial separation of forward and return currents and eventually to the filamentary structure. The currents subsequently get Weibel-separated, followed by the tearing and coalescence instabilities, which produce current channels and thereby filamentary magnetic field structures. The present study captures these structure after some coalescence has taken place and monitors the subsequent evolution as a function of time. These results are fundamentally interesting in the context of fast ignition of laser fusion [1], laser-based acceleration of protons, ions and neutral particles [4], the feasibility of experimentally verifying such instability mechanisms in astrophysical magnetic fields [1] and simulating intra-planetary matter existing at ultrahigh pressures [5].

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Poster P34

The equation of state of stellar explosion products

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Poster

H_2O,CO_2 and N_2 are the major explosion products of the star. The equation of state (EOS) of these explosion products is key important for studying the explosion properties of the star. In this paper the EOS of single product is described by Rossmodification of hard-sphere variation theory. The interactions between different molecules are evaluated by the Lorent-Berthelor combination rules and the mixing parameters are determined by simple explosives. The results agree with experiment data and the other theories data well.

Poster P35

High Current Powerful Discharge in High Density Gas

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Poster

Powerful gas discharge at high and super-high pressures is a part of high energy density physics and extreme state matter physics. Phenomena arising from the interaction of intense energy fluxes with matter, properties of matter under extreme conditions at high pressures and temperatures are very challenging diagnostic task. The discharge can be used as a laboratory model of astrophysical objects for modeling radiative transport in star photosphere, equations of state for matter, shock wave propagation in plasma, etc.

In the reports research results for discharge, initiated by wire explosion, in hydrogen and helium at high initial density gas (initial pressures of 1–200 MPa) and current amplitudes up to 1.5 MA are presented. Diagnostics of processes in such discharges at these densities are extremely difficult scientific and technical problems. Basic difficulties of diagnostics of the discharge with such parameters are connected with the high density of plasma. Optical methods give information only about peripheral areas of the discharge because of the strong absorption of radiation from the central area. We have developed original high-speed diagnostic methods in the optical and x-ray regions, which allowed us to see the discharge channel structure.

The phenomena are discussed, which are determined by high density of the gas surrounding the discharge channel: drop in channel brightness with gas density increase and energy input into volume; photoionized pure gas plasma formation in transition zone between discharge channel and gas; possibility of energy density increase in discharge channel, which can be caused by the resonance of the acoustic oscillations in discharge chamber volume and the channel oscillations connected with alignment of the gas-kinetic pressure and the magnetic pressure.

Poster P36

Experimental study on jet formation and propagation by use of Gekko-XII laser system

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Poster

We report the experimental study on jets, which are one of astrophysical high-energy phenomena, as a model experiment with a high-power laser. Jets have been observed in a lot of astrophysical objects: protostars, active galactic nuclei, and binary systems, however, there remains various open questions on the mechanisms by which the jets are launched and collimated. The experiment was carried out at Institute of Laser Engineering, Osaka University, using Gekko-XII laser system. The multiple pulses were focused on a thin plastic foil, to generate collimated plasma jet. The jet structure was observed with optical diagnostics such as shadowgraphy, interferometry, and streaked optical pyrometry. The velocity, temperature, and density were measured with collective Thomson scattering. We investigate the jet propagation in an external magnetic field and/or in ambient low-density plasmas, compareing with a particle- in-cell simulation.

Poster P37

Numerical study of radiative shocks applied to astrophysics

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Poster

For sufficiently large Mach number shock-waves, one can no longer neglect radiative effects and we have so-called radiative shocks. These shocks are involved in many astrophysical processes such as astrophysical jets, supernovae and supernova remnants. Even though the research on astrophysics radiative shocks is relatively new, the development of high energy astrophysical laboratory studies over the last years has been crucial in order to have a better understanding of these phenomena. In fact, our research group now has detailed experimental results of experiments conducted with high energy laser (GEKKOXII, LULLI2000, LIL) that can be compared with numerical simulations.

HADES is a 2D numerical code, coupling hydrodynamics with radiative transfer that has been developed and upgraded by our team group. The radiative transfer is theoretically described by the M1-model such that it is possible to use the code for a large range of radiative regimes.

Thus, based on previous experiments from our team and thanks to the HADES code, we have been able to compute the evolution of a stationary radiative shock propagating in krypton gas. First, we have quantified the influence of opacities, or mean free path of photons, on shock's properties and relevant physical quantities of the problem (temperature, density, radiation energy...). Therefore, several categories of radiative regimes have been identified and linked with examples from literature.
Then we have used the values of krypton opacities provided by TOPS to compute the realistic case of radiative propagating shocks in this gas. These numerical simulations are thus ready to be compared with the experimental results in order to achieve a better understanding of radiative shocks formation and propagation.

Poster P38

Collisional-radiative simulations of a supersonic and radiatively cooled aluminum plasma jet in vacuum.

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Poster

A computational investigation based into collisional-radiative simulations of a supersonic and radiatively cooled aluminum plasma jet is presented. The jet was produced on the MAGPIE generator and is formed by ablation of an aluminum foil driven by a 1.4 MA, 250 ns current pulse in a radial foil Z-pinch configuration. In previous works [1], the experimental setup, plasma diagnostics and the dynamics of plasma formation were described in detail, and moreover, MHD simulations of the experiments were performed with the GORGON code [2].

In this work, kinetic populations and radiative properties simulations of the jet in different theoretical approximations were performed. In particular, local thermodynamic equilibrium (LTE), non-LTE steady state (SS) and non-LTE time dependent (TD) models have been considered. This study allows us to make a convenient microscopic characterization of the aluminum plasma jet. Besides, the influence of the ion transport and the photon reabsorption effects were analyzed in the collisional-radiative simulations.

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Poster P39

Ionization potential depression in warm and hot solid density plasmas

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Poster

Understanding the physical properties of matter under high density and temperature is of prime importance for a good description of the interior of stars or in inertial confinement fusion research. Around solid density the restricted volume available to individual ions results in the so-called pressure ionization, that adds electrons to the thermally ionized ones. Depending on the temperature the environment of every ion may be modified in a complex way, with consequences on the equations of state or the opacities.

Developments in laboratory astrophysics now allow to diagnose those plasmas and put constraints on their modeling. The effect of density on the ionization potential depression (IPD) was recently measured for aluminium using the LCLS x-ray free electron laser (Ciricosta et al, 2012) or a combination of short pulse/long pulse at the new laser facility ORION (Hoarty et al, 2013). The first experiment demonstrated that the usual Stewart-Pyatt model predicts a too small depression, with the Ecker-Kröll model performing well. The second one was however in better agreement with the Stewart-Pyatt predictions.

We have applied our average ion model (Massacrier, 1994; Potekhin et al, 2005; Massacrier et al, 2011) to the case of an alumimium plasma around solid density. In contrast with average atom models, a self-consistent scheme is solved independently for each ion charge of a given element. Free electron densities are computed quantum mechanically and include resonances, while bound states are broadened into bands. We illustrate the importance of correctly taking into account the number of bound electrons (and not merely an average) to obtain free electron density profiles (and hence IPD) around each ion. We also show the influence of temperature in shaping these profiles in the range relevant to the experiments.

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Poster P40

A 3D Lagrangian scheme applied to the simulation of non-stationary Rayleigh-Taylor instabilities in a supernova remnants

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Poster

Several astronomical flows can be studied thanks to the gas dynamic equations under the Lagrangian formalism. Here we propose to study the supernova remnants dynamic during the blown-up by a central pulsar. Rayleigh-Taylor instabilities appear at the internal face of this gas shell perturbing the flow. The scheme used here is a multi-dimensional second-order cell-centered Lagrangian scheme. This scheme satisfies a semi-discrete entropy inequality and conserves globally the momentum and the total energy. The robustness of the code is tested first on the case of a strong isentropic compression, then we study the blown-up of a spherical shell with and without perturbation at the interface. Comparison are made with the analytical model.

Poster P41

Optimization of an electromagnetic generator for strong shocks in low pressure gas

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Poster

Accretion and ejection processes are key elements to predict the evolution of Young Star Objects (YSOs) and their feedback to the interstellar medium. The observational signature of accretion is correlated to the presence of a strong shock which forms when the matter from a circumstellar disk hits the photosphere of the star. In this context, laboratory plasma astrophysics is a powerful tool to study the dynamics of these hypersonic processes. In parallel with experimental studies of radiative shocks in moderate pressure Xenon, driven by high-power lasers (U. Chaulagain et al., this conf.), strong shocks in low pressure rare gases can be generated using a very different technique: an electromagnetic gun. A low-inductance high-voltage generator at the kJ level drives a high current pulse, peaking at 150 kA in a 1-µs rise time. The principles of plasma sheath formation and acceleration are presented and modeled with a lumped circuit. A parametric study of the generator, coupled to the moving plasma, is presented, leading to proposed optimized geometries. A passive optical diagnostic is used to measure the shock profile and speed (typ. 20 km/s). In order to pre-process other complementary diagnostics, detailed MHD simulations, using the GORGON code, give reference information for the plasma parameters of the moving ionized sheath.

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Poster P42

Equation of states and transport properties of mixtures in warm-dense-matter regime

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Poster

We have performed average-atom molecular dynamics (AAMD) to simulate the CH and LiH mixtures in warm-dense-matter regime, and obtained equation of states and the ionic transport properties. The electronic structures are calculated by using the modified average-atom (AA) model, which have been including the broadening of energy levels, and the ion-ion pair potentials of mixtures are calculated based on the temperature-dependent density functional theory (td-DFT). The ionic transport properties, such as ionic diffusion and shear viscosity, are obtained through the auto-correlation functions. We use the AAMD model to calculate the equation of states and transport properties for carbon, hydrogen and lithium, hydrogen mixtures in a wide region of density and temperature. And we also consider the ionic number effect on the properties in molecular dynamics simulations. Through our analyzing the results, it is shown that the ionic number will affect the transport properties. And it has also proved that transport properties not only depend on the ionic mass but also on collision cross section.

Poster P43

Proton emission measurements from astrophysically relevant magnetic tower jets

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Poster

We present novel proton and ion self- emission data obtained from astrophysically relevant magnetic tower jets on the MAGPIE generator. The jets were created using a 1.4 MA, 250 ns current pulse which was discharged into a tungsten radial wire array load. The dynamics of this load are characterised by the formation of a magnetic cavity which contains within it a magnetically collimated jet. Some aspects of the jet launching and collimation mechanisms are similar to those predicted by models of jets from accretion discs.

Time-integrated proton and ion emission was recorded from the magnetic-tower jet on CR-39 detectors using pinhole and fly-eye cameras. The regions of ion emission are compared with time resolved optical probing and soft x-ray self-emission. The results indicate that the bulk of the emission is low energy protons which are emitted from the background plasma surrounding the jet with the flux being greatest on axis. A fly-eye camera consisting of a series of collimating tubes was used aluminium filters to localise the emission of higher energy protons. Preliminary results from this indicate that higher energy (> 600 keV) protons are emitted from the axis of the magnetic jet during the formation of current driven MHD instabilities.

Poster P44

Radiation magnetohydrodynamic flows: New scaling laws for laboratory astrophysical experiments

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Poster

Magnetic field plays an important role in astrophysical environments and is the source or a key element of many physical processes encountered in various high-energy astrophysical environments such as reconnection, instability developement or accretion [1,2,3]. The capability to produce in laboratory radiation hydrodynamic flows submitted to intense magnetic fields is a real opportunity in order to progress in their modelling.
The similarity properties of these plasmas have already been the subject of different works [4,5,6]. In this work we propose to extend the study of the similarity properties and the development of scaling laws to new regimes of radiating magnetized plasmas [7]. We also discuss the possibility to produce flows similar to astrophysical ones in laboratory with current powerful facilities.

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Poster P45

Radiative condensation in optically thin plasmas: From proto-stellar molecular clouds to laboratory plasmas

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Poster

Radiative condensation plays a fundamental role in the understanding of the structure and the dynamics of the interstellar medium [1]. Recently, this phenomenon is at the basis of the study and the interpretation of high-energy-density experiments achieved with powerful facilities. In order to better understand this phenomenon, some theoretical developments have been performed to provide analytical solutions [3,4].

In this work we present a new class of self-similar solutions which generalizes all the results obtained until up to now to describe the radiative condensation. We built, with the Burgan-Feix-Munier transformation, a new type of self-similar solutions where the hydrodynamical and cooling times are completely independent. Basically, this new approach allows us to build more general solutions than those obtained with Lie symmetries [3, 4]. When we apply these results to molecular cloud dynamics, the different solutions describe two hierarchical levels of the radiative condensation: firstly the fragmentation of molecular clouds to substructures, then the condensation of each proto-stellar cloud. These analytical results are compared with numerical simulations and we propose to discuss the relevance of these solutions in order to describe the condensation of molecular clouds.

Finally, the similarity properties of this radiation hydrodynamic phenomenon are presented and adapted scaling laws are developed, showing that we can study the radiative condensation in laboratory with the powerful lasers. We propose some patterns of target to achieve these studies in laboratory.

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Poster P46

The scalability of astrophysical outflows: numerical simulations of the dynamics of high-energy density laboratory supersonic flows propagating into vacuum and ambient gas

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Poster

The possibility of performing well-designed laboratory simulations to study the physics of outflows emitted by young stellar objects can contribute to a better understanding of their dynamical and morphological properties.

In this work we present numerical simulations to analyze the structure, the dynamics and the stability of laboratory collimated outflows produced with powerful lasers. The numerical results are compared with analytical self-similar models [1] as well as with outcomes of experiments realized on LULI2000 facility [2,3]. The astrophysical relevance of these laboratory supersonic flows is also discussed.

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Poster P47

Relevant experiments to study magnetic cataclysmic variable radiation accretion flows in laboratory : similarity properties & HED numerical simulations

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Poster

Magnetic cataclysmic variables (mCVs) are binary systems containing a highly magnetized white dwarf which accretes matter from a late type Roche-lobe filling secondary star. The presence of intense magnetic fields, radiation and hydrodynamics implies a rich range of behaviors at different spatial and time scales. The radiation in the X-ray domain collected from these objects mainly comes from an unresolved high-energy area near the white dwarf surface where the matter is accreted. This radiation could give us insight on the system parameters such as the white dwarf mass or the accretion rate providing that a correct model is used to describe the system. The possibility of reproducing similar phenomena in laboratory with powerful facilities is a unique opportunity to increase our understanding of the physics of accretion processes.

In this work, the similarity properties of the high-energy region considering the different accretion regimes is discussed. Based on these theoretical results, we present our conclusions concerning the first experimental results obtained in the context of the POLAR project [1,2] supported by multi-dimensional high-energy density physics numerical simulations. Furthermore, the possibilities and the limits of experimental simulations of accretion processes in mCVs with powerful lasers are reviewed.

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Poster P48

New similarity concepts for high-energy density physics: extended similarity and application to Marshak wave

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Poster

Diffusive radiation heat waves, or Marshak waves [1], play an important role in energy transport for many astrophysical and HEDP plasmas. For instance, these waves take place in the heating of accretion disk around compact star like white dwarfs or neutron stars, in inertial confinement fusion [2] and more generally in the transport of energy in high energy density physics experiments. From the value of the Mihalas number (noted R) [3], the Marshak waves can be classified in two types: the weakly radiative Marshak waves (WRMW), which are characterized by R >> 1, and the highly radiative Marshak waves (HRMW), with R ≈ 1. The different types of Marshak waves present similarity properties and scaling laws [3] [4] which allow us to reproduce them in laboratory with high-power facilities. However, the scaling invariance requires the conservation of dimensionless numbers and restrictive constraints on the equation of state and opacities which limit the experimental studies.

In this work we present new concepts of similarity (extended similarity), based on the transformation group theory, which allow us to change the EOS and opacity between the astrophysical and laboratory systems and do not conserve the main dimensionless numbers. The main result of this work is that HRMW physics can be studied with a WRMW if some constraints are satisfied. These transformations open new perspectives to study astrophysical radiation hydrodynamic flows in laboratory.

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Poster P49

Study of the soft X-rays excess emission in magnetic cataclysmic variable systems with powerful lasers

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Poster

Magnetic cataclysmic variables or polars are binary systems containing a highly magnetized white dwarf (B ≈ 10 – 230 MG) which accretes matter from a late type Roche-lobe filling secondary star [1]. In these systems, the magnetic field is strong enough to prevent the formation of the accretion disk and to channel the accreted plasmas up to the compact object magnetic poles, leading to the formation of accretion column. In the *standard model*, the impact of the supersonic free-fall accreting matter with the white dwarf photosphere generates a reverse shock (accretion shock), which heats the infalling plasma up to 10-50 keV [2-3]. The understanding of the physics of this emitted X-ray region is fundamental since it is at the base of the determination of the white dwarf properties.

Although the *standard model* explains the global astronomical observations, the energy balance (ratio between the hard and the soft X-rays) is not correctly reproduced by theoretical models (theory : LhX/Lsoft ~ 2.0, observations : LhX/Lsoft ~ 0.1 [4]). In order to explain this disagreement, various models [5] have been developed to explain the physics of interaction between the accretion flows and the white dwarf photosphere.

In this work the possibility to explore this problematic in laboratory with powerful laser experiments will be studied. The similarity properties of impact physics will be discussed. A numerical study will be presented where the POLAR target design proposed in [6] is modified to propose astrophysical relevant experiments to study the impact physics.

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Poster P50

Preliminary results from a long-duration x-ray drive experiment to study photoionized plasma equilibrium

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Poster

The production of photoionized plasma equilibrium in the laboratory is a standing challenge of high-energy density laboratory astrophysics. A key consideration is the availability of a long-duration x-ray drive since achieving photoionized equilibrium requires plasma lifetimes of tens of nanoseconds1. We discuss preliminary results from a new experimental approach, i.e. the “gatling gun” platform, in which three halfraum targets were sequentially irradiated by three OMEGA-EP laser beams, i.e. one laser beam per halfraum. The laser beams were operated in the long duration mode of 10ns pulses and stacked up in time so that the end of a given laser beam overlapped with the rise of the next one. In this way, a sustained x-ray drive of 30ns duration and characterized by a radiation temperature Tr=90±10 eV was experimentally demonstrated2. This x-ray source was used to drive a plastic-tamped, 0.5mm thick Ti foil in order to produce a photoionized Ti plasma. The x-ray self-emission of the Ti plasma was recorded with a spectrometer. The observation shows significant ionization of Ti and the emission of characteristic L-shell line transitions. We model the hydrodynamic expansion of the Ti sample, estimate the density of the plasma and the importance of collisional processes in the plasma atomic kinetics, interpret the spectroscopic measurements, and discuss the extent to which photoionized plasma equilibrium was achieved in the experiment.

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Poster P51

Results from a photoionized plasma experiment at the Z facility relevant to astrophysics

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Poster

Detailed x-ray spectral observations performed with the Chandra and XMM-Newton orbiting telescopes provide critical information on the state of photoionized plasmas. However, the complexity of the astrophysical environment makes the spectral analysis challenging, and thus laboratory experiments are important for data interpretation and benchmarking of modeling codes1. The Z facility at Sandia National Laboratories is a powerful source of x-rays to produce and study in the laboratory photoionized plasmas relevant to astrophysics under well characterized conditions. We discuss an experimental and theory/modeling effort in which the intense x-ray flux emitted at the collapse of a z-pinch implosion driven by the Z pulsed-power machine is employed to produce a neon photoionized plasma. The broadband x-ray radiation flux from the z-pinch both creates the plasma and provides a source of backlighting photons to probe it through K-shell line absorption spectroscopy. The plasma is contained in a cm-scale gas cell that can be located at several distances from the z-pinch and filled with different neon gas pressures. The flexibility of the set up permits a systematic study of the photoionized plasma for a range of ionization parameter values between 1 and 100 erg cm / s. The plasma is diagnosed via transmission spectroscopy using a 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 a rich line absorption spectrum that spans several ionization stages of neon including Be-, Li-, He- and H-like ions. Modeling calculations are used to interpret the transmission spectra recorded in the experiments with the goal of extracting the charge- state distribution, electron temperature and the radiation flux driving the plasma, as well as to determine the ionization parameter of the plasma. In addition, the heating of the plasma and the comparison between the electron temperature obtained from the experiment with results from radiation-hydrodynamics and kinetic simulation codes is discussed.

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Poster P52

Radiative shocks at PALS: latest results and future prospects

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Poster

Being able to produce and diagnose radiative shocks under controlled laboratory conditions is a key aspect to understand their role in astrophysical processes such as accretion in stellar formation. The ongoing study of radiative shocks using high-power lasers has significantly advanced our understanding on the physics of these complex flows. In particular, experiments at the Prague Asterix Laser System (PALS) have demonstrated the formation of radiative shocks in Xenon with a characteristic velocity of 50-60 km/s.

Latest results on the generation on radiative shocks at PALS demonstrate the feasibility of fielding novel probing techniques such as time-resolved imaging using an X-ray laser at 21.2 nm, allowing to probe simultaneously the high-density shock-front together with the lower-density radiative precursor in front of the shock. These results will be compared with 2-D radiative-hydrodynamic simulations using the code ARWEN.

Future experimental campaigns will focus on spectroscopic measurements of the different shock regions together with new experimental configurations such as the interaction of counter-streaming radiative shocks. These prospects will be presented and discussed from both experimental and simulation point of view.

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Poster P53

Laser produced radiative shock waves in Xe: simulation of previous PALS experiments

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Poster

We present a study of laser produced radiative shocks in Xenon gas with an AMR hydrodynamic code with multigroup radiation transport called ARWEN [1]. Our aim is to reproduce the results obtained in PALS experiments [2] with simulations of the actual target configuration, taking in account the uncertainties in the target fabrication. We will extend the study to other materials as Ar or Kr for the filling gas.

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Poster P54

Preliminary characterization of a laser-generated plasma sheet

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Poster

A reverse shock is a shock formed when a freely expanding plasma encounters an obstacle. Reverse shocks can be generated by a blast wave propagating through a medium. They can also be found in binary star systems where the flowing gas from a companion star interacts with the accretion disk of the primary star.

Previous experiments [Krauland et al 2013] created a flowing plasma, which represents the flowing plasma from the secondary star. This flow interacted with a stationary object, which represented the disk around the white dwarf. Future experiments will create a flowing plasma to represent the white dwarf's disk and create a reverse radiative shock from the interaction of two flowing plasmas.

We will present the results from recent experiments to create a flowing plasma sheet. This includes characteristics of the plasma sheet such as the spatial extent, density and velocity. We will also discuss the implications for future experiments.

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Poster P55

Identical Algorithm of Radiative Transfer Across Ultrarelativistic Shock in Different Inertial Frames

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Poster

We have investigated radiative transfer in relativistic shocks that can produce gamma rays. High energy photons can be emitted in ultrarelativistic flows even if matter temperature is not so high. It is necessary to develop a coupling code of relativistic hydrodynamics and radiative transfer for realistic calculations of gamma-ray bursts. We have constructed numerical methods that involve consistent transform between comoving frame and observer frame for radiative transfer simulations on relativistic background flows. We considered shock rest frame and shock moving frame using Rankine-Hugoniot relations, and implemented three-dimensional Monte Carlo simulations in each frame. In addition, we transform obtained photon direction distributions and spectra from each frames to same frames. Taking into account Thomson scatterings and Compton scatterings, we conclude that obtained direction distributions and spectra have a little difference among each frames if appropriate time duration for computation of the background flow is selected. Spectra show that the peak energy is shifted by the Doppler effect and the MeV-order photons are produced by the inverse Compton scattering in ultra relativistic flows.

Poster P56

SHAPING THE SPECTRUM OF HOT ELECTRONS USING STRUCTURED TARGETS

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Poster

Hot electron generation is a crucial aspect of the intense laser solid interaction. Proper energy and angular distributions of the fast electrons greatly benefit subsequent processes such as X-ray and gamma-ray production and ion acceleration. Fast electrons generated using simple flat targets are large in charge, but usually have high divergence, low energy and broad spectrum, which limit the efficacy of their applications. We have used 3D LSP PIC simulations to develop a way to generate high energy, low divergence electrons using structures (spikes or fins) on the target front surface. When an intense, ultra-fast laser pulse interacts with these structures, electrons at the tip are accelerated via direct laser acceleration to energies much higher than the ponderomotive energy. The electric and magnetic fields from these super-hot electrons and the return current inside the structures guide the electrons, leading to a small divergence angle. Varying the structure shape can further tune the electron spectrum.

This work is supported by United States AFOSR Young Investigator Program under contract FA9550-12-1-0341 as well as US Department of Energy contract DE-NA0001976. Computing time is provided by the Ohio Supercomputer Center.

Poster P57

Magnetic field amplification of interpenetrating jets relevant to astrophysical Herbig-Haro objects

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Poster

Magnetic fields found in the Veil and Orion molecular clouds range from 50 μG to a few G, which are too large to be the result of advection of jet frozen-in fields. These magnetic fields exceed the average field in the interstellar medium in the galaxy (~ a few μG). It has been proposed that turbulent amplification may contribute to their growth. Here we report laboratory experiments that show magnetic field amplification in laser-produced jets relevant to Herbig-Haro (HH) objects. Furthermore, magneto-hydrodynamics (MHD) turbulence is believed to excite waves that result in the acceleration of electrons above their thermal values, and the dissipation of these energetic electrons could further heat the gas. Excitation of lower-hybrid waves can explain the production of high energy electrons and the observed x-ray emission from comets and supernova remnants.

Poster P58

Investigating Configuration Interaction effects on Fe and Ni opacities with HULLAC-V9 and STA codes for stellar to laboratory experimental conditions

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Poster

We investigate the density and temperature dependence of Configuration Interaction effects on M shell Dn = 0, n=3 transitions over a wide range of thermodynamic conditions with the help of full CI HULLAC-v9 (1) and STA (2) calculations. We concentrate on these transitions for both reasons, these transitions are the most sensitive to CI effect and they give the most important contribution to the large M shell peak of the opacity spectrum. Thus opacity spectra and their corresponding Planck and Rosseland mean can be affected by approximations on the CI treatment (1, 3). Results are given for conditions which cover stellar envelopes to laser experiments already studied inside the International OPAC Consortium (4), 10^7 < rho (g/cm3) < 10^2, 10 eV < T < 40 eV. The motivation is the understanding of anomalies put in evidence by helioseismology and asteroseismology which can be attributed to an insufficient knowledge of stellar opacities in the region where there is an iron peak, around log T = 5.2 (5) and for mass densities in the range 10^-7 < rho (g/cm3) < 10^-5. Some comparisons with OPCD opacity data base results (6) are also presented.

Fig.1 : An example of CI effects on iron spectral opacity spectra at T= 15.3 eV and Ne= 3.2 10^16 cm^-3 : HULLAC-v9 (full CI and CI in NRC modes) and STA results.

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Poster P59

Counter propagating plasma jet interaction and shock formation for laboratory astrophysical phenomena on a small scale current driver

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Poster

In this work we demonstrate the ability of a small linear transformer driver (LTD) yielding 250 kA in 150 ns to produce counter-propagating flows. The flows were produced by two vertically opposed conical arrays, each comprised of 8 wires, separated by a 1cm spacer. With this array configuration we were able to produce two plasma jets with velocities on the order of 100-200 km/s that converge at the center of the array. Using optical probing diagnostics, a shock wave was observed to form at the colliding region that remains stationary for an extended period of time. After formation, a bow shock-like structure is observed, which may be due to small differences in the density and/or speed of the jets. A mean free path larger than the shock scale is estimated for aluminum, making it very promising for the study of astrophysical collisionless shocks. Hybrid and fully kinetic particle-in-cell simulations have been implemented to study the physics of shock formation and evolution. The magnetic field advection by the plasma flows and its effect on the shock formation will be discussed.

Poster P60

Simulations of HED laboratory astrophysics experiments of accretion shocks in polars

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Poster

The POLAR project [1], studies the accretion shocks in magnetic cataclysmic variables (mCVs). These are binary systems containing a highly magnetized white dwarf which accretes matter from a secondary star. Due to the intense magnetic field, the accreted matters is guided by the magnetic field lines and falls with supersonic velocity onto the white dwarf surface, creating a reverse radiative shock. An experimental target design was proposed to reproduce these accretion shocks in an astrophysically relevant regime through scaling laws [2].
In this poster, we will present 2D radiation hydrodynamics simulations using the FLASH code used to interpret recent laboratory astrophysics Polar experiments performed on LULI2000, ILE and Orion laser facilities.

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Poster P61

Oblique shock: regular to irregular propagation

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Poster

Equations of state of materials play an important role in the studies of astrophysics, inertial confinement fusion, and other related fields. High power pulsed lasers have been used to achieve multi-Mbar pressures using planar shock experiments and have demonstrated the possibilities to achieve very high pressure. In others experimental domains such as explosive and gas gun experiments, extremely high temperatures, pressure, and densities have been achieved with the use of oblique shock waves. The goal of this first experiment was to investigate the possibility of generating and controlling oblique shock waves using intense laser pulse [1].
The target is composed of a conical shape (transparent to visible light) filled with CH foam. This conical target design has been already studied as a promising candidate for inertial confinement fusion [2] but it has also been used to study physical properties of materials at extremely high temperature, pressure, and density [3]. By changing material composition of the cone, angle and incident shock velocity we can generate different reflection and transmitted shock conditions (regular and irregular cases). In specific conditions (irregular case), we can observe the generation of a Mach wave, especially interesting because of its intensity. Mach wave propagation has been already used with explosive technique to study material in very high pressure. The purpose of this experiment was then to study and diagnose the different cases by changing the cone angle and the initial shock velocity. The experiment has been performed at the LULI2000 laser facility and results such as VISAR and SOP measurements will be presented.
A second type of target has been tested at LLNL using JUPITER facility (JANUS laser beams) using a fiber target in which the impedance mismatch between the core of the fibre and the envelope generates a Mach wave. This second geometry has been proposed by J.L. Brown [1] to strongly enhance the shock pressure. 1D and 2D VISAR has been set up as well as SOP measurements.
This project is the first step in order to demonstrate the advantages of this complicated experimental design to study dense matter where higher pressures can be achieve with a given laser intensity.

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Poster P62

High-Velocity Collision-less Shock Production in Magnetized Plasmas via High-Intensity Lasers

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Poster

A major question in astrophysical expanding and colliding plasmas concerns the formation of collision-less shocks and how this process leads to high-energy radiation and energetic particles. Such processes occur in many astrophysical objects (e.g. supernovae remnants (SNRs), micro-quasars, Gamma-ray bursts (GRBs), pulsars, blazars) and are thought to be the source of the most energetic cosmic rays. While collision-less shocks have been studied on high-power, high-energy lasers (e.g. Omega) previously, such studies have been limited to the outflows of relatively low-velocity (< 0.01c) plasmas. In this work performed on the Titan laser in the split beam configuration (70 J/beam, 650 fs), we exploit the target normal sheath acceleration (TNSA) mechanism to create high-velocity (> 0.1c), counter-streaming proton plasmas. To mimic magnetized outflows occurring in astrophysical objects (e.g. SNRs) we impose a 20 T (0.2 MG) external magnetic field. Using Mach-Zehnder interferometry, this magnetization is observed to create what appears to be an increased-density, long-lived (~ 100 ps) shocked region as opposed to the exponential density decay observed in the non-magnetized cases. Particle-in-cell (PIC) simulations are used to reproduce the observed density maps using the observed initial plasma parameters. This allows an in-depth understanding of the underlying physics and the consequences for astrophysical scenarios.

Poster P63

Laboratory investigations of magnetic wave structures emitted ahead of parallel shocks

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Poster

High power laser facilities now enable matter to be placed in highly energetic conditions relevant to astrophysical objects, helping us understand processes such as the formation and evolution of astrophysical shocks. Parallel shocks, that is, shocks propagating parallel to the direction of an ambient magnetic field, are poorly understood, despite the importance of collisionless parallel shocks in processes such as cosmic ray acceleration and the formation of the Earth's bow shock. A particular difficulty arises because of the complex interplay of non-thermal particle populations and wave structures in the foreshock, making numerical and theoretical studies challenging. Recent experiments we conducted at the Institute of Laser Engineering, Japan, have accessed, in a collisional environment, at least part of a foreshock, in the form of transverse magnetic field waves that are seen propagating ahead of the shock. Transverse magnetic field waves are associated with observations of the Earth's parallel bow shock and are important in the formation of collisionless shocks.

Poster P64

X-ray spectral output as a possible indicator of mix models in plasmas

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Poster

Dopant atoms emit X-rays that are dependent on the local plasma conditions, such as electron and ion densities as well as electron temperature and local electromagnetic fields. Here we will show how imaging the spectra, from different spatial distributions of spectator dopants, may be used to distinguish between different mix models. Radial spectral imaging would be used to infer the local plasma conditions. Absolute emission would give the spectator density distribution.

Poster P65

Quasi-periodic oscillations in accreting magnetic white dwarfs: Observational constraints in X-rays and optical

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Poster

Magnetic cataclysmic variables (also called 'Polars') are binary systems in which a highly magnetic white dwarf accretes matter from a dwarf secondary star, via a column. Matter releases its gravitational energy through a stand-off shock close to the white dwarf surface, mainly via Bremsstrahlung X-ray emission and cyclotron visible radiation. Some of these Polars are known to show (0.3-1 Hz) quasi-periodic oscillations (QPOs) in visible light, which have been related to shock instabilities.
No systematic search for QPOs has yet been done in the X-rays.
We have analyzed a large sample of Polars observed with the X-ray XMM-Newton satellite and provide upper limits on QPOs in the range 0.1 – 5 Hz.
These results are compared to theoretical predictions of 2D hydrodynamical models developed in the context of the POLAR project. The comparison between observations and numerical simulations provides important constraints of the influence of the mass accretion rate and the magnetic field strength on the development of instabilities and damping processes.

Poster P66

Electron laser wakefield acceleration enhanced by stochastic heating

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Poster

In this presentation, electron acceleration by a laser wakefield is sstudied. Laser wakefield is created by the propagation of an intense and short laser in under-dense plasma. The wakefield becomes an ion bubble with dense surface layer of electron in the case of very intense laser. The charge separation creates an intense electric field (up to 200 GV/m) which could accelerate electrons to high energies (100 MeV to few GeV) with a few centimeters of plasma. The injection of electrons is realized with a low intensity counter-propagating wave which collides with the high intensity laser.

In this presentation, various configurations are examined.

First, we show in the framework of Hamiltonian analysis that an electron in the fields of two lasers linearly polarized, undergo stochastic heating for some laser intensity and derive Chirikov criterion. Stochastic heating injection process is compared to cold injection where only the beatwave created during collision of two circularly polarization allows electrons to enter through the front of the wakefield . We derive by PIC (Particle In Cell) simulations, conditions on laser and plasma parameters where injection with stochastic heating is more efficient i.e. it accelerates more electrons.