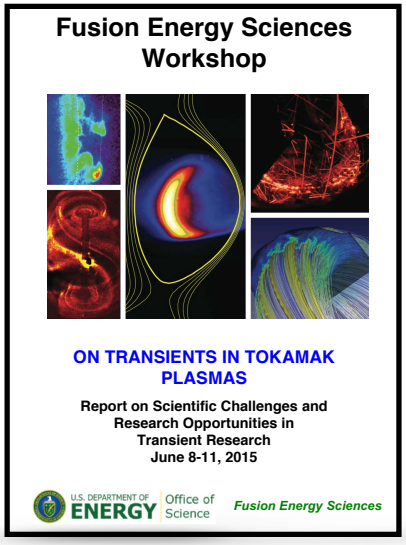
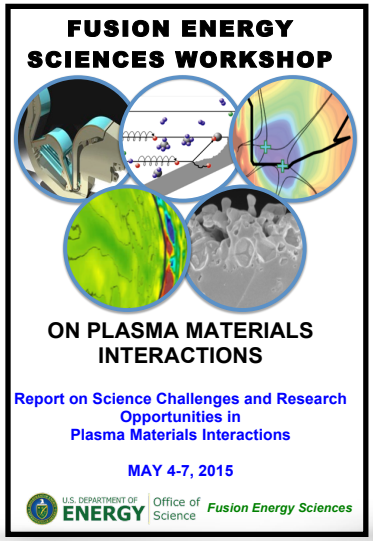
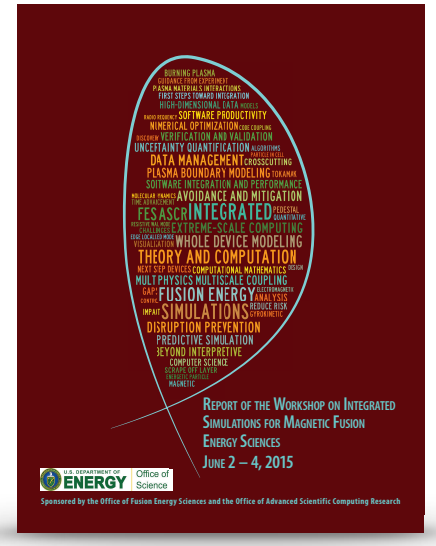
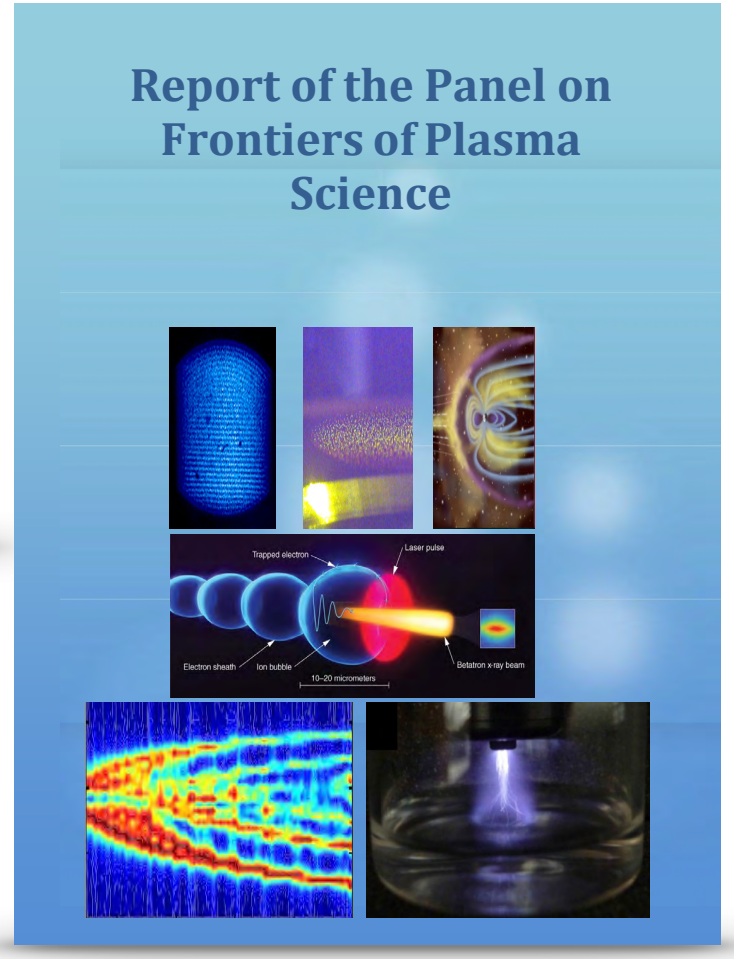
Discussion on the Draft Report: Frontiers of Plasma Science









The Fourth Workshop Report →

Friday, August 26th, 10:45 am in
Theory Seminar Room, T169

https://www.orau.gov/plasmawkshps2015/report.htm

Workshop and Panel Process

- Co-Chairs: Jonathan Wurtele and Fred Skiff
- 56 Panel Members (incl Fisch, Kaganovich, Kunz, Mikhailova, Stone, Zweben)
- 200 White Papers
- 100 Presentations at Open Town Hall (June 2015)
- Two closed panel meetings (Aug and Oct 2015) focused mostly on first charge and preparation of the scientific narrative.

The Frontiers of Plasma Science

Mike

- **Extreme States of Matter and Plasmas** (Chapter 2)

How do plasmas behave under extreme conditions where our current descriptions fail?

Igor

- **Understanding the Physics of Coherent Plasma Structures** (Chapter 3)

How does plasma electrical self-organization work, both in physical space and in phase space, and how can we control it?

Mike

- **Understanding the Energetics of the Plasma Universe** (Chapter 4)

What processes control the transformation of energy between forms, the transfer of energy across vast differences in scale, and the transport of plasma energy in the Universe?

Igor

- **The Physics of Disruptive Plasma Technologies** (Chapter 5)

How can efficient interactions between electromagnetic fields and particle motion be established and controlled?

Igor

- **Plasmas at the Interface of Chemistry and Biology** (Chapter 6)

How can we describe and control the interaction of plasmas with solids, liquids, and gases?

- **Cross-Cutting Motifs** (Chapter 7)

Theory and Computation, Plasma Diagnostics, Data Resources

Take-Away from the Frontiers of Plasma Science…

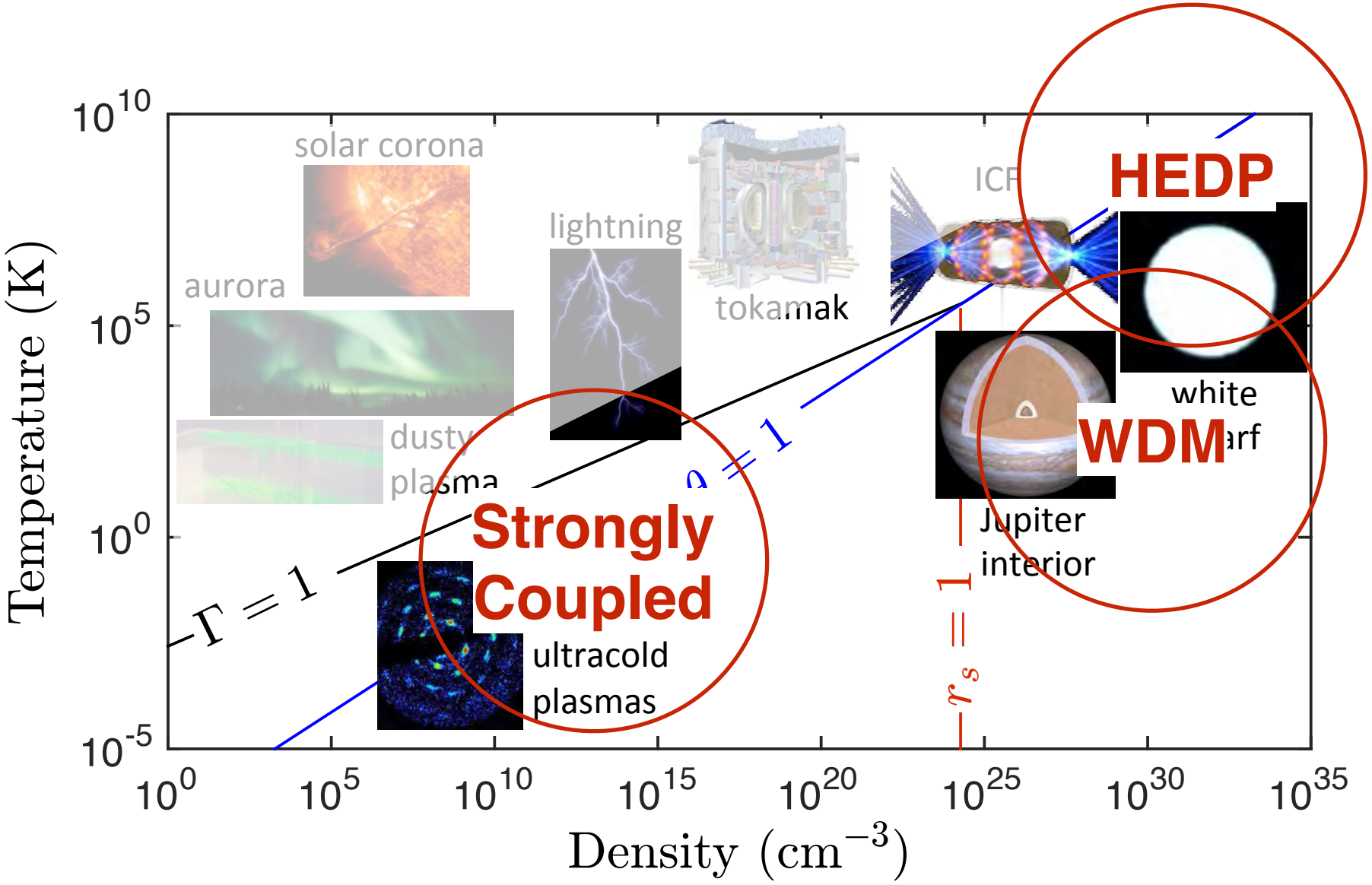
- *The Frontiers questions bridge vast scales:* from astrophysical phenomena to creating & controlling plasmas at the nanoscale
- *The Frontiers advance both science and technology:* both fundamental phenomena and applications for societal benefit
- *The Frontiers underlie critical mission elements of multiple agencies*: DOE, DOD, NSF, NNSA, NASA, EPA, NIH, …
- *The Frontiers need multiple research facilities, all sizes from table-top to large-scale, sophisticated theories and models, state-of-the-art computational algorithm development, …*

Extreme States of Matter and Plasmas

Extreme states of matter and plasmas reveal the age of our galaxy, they can lead to the formation of matter from boiling the vacuum, and they determine the dynamics of complex and correlated plasmas that exist in the cosmos and can be created and controlled in the laboratory.

- **WDM Frontier**: (strongly coupled ions and quantum degenerate electrons) at the heart of many unsolved problems in planetary science and stellar astrophysics
- **HEDP Frontier**: e^-/e^+ and nonlinear QED via intense photon colliders
- Probing **Fundamental Symmetries of Nature**: Strongly-coupled (classical) plasma and antimatter plasma

Extreme States of Matter and Plasmas



Extreme States of Matter and Plasmas

- What are the material properties of WDM and how can we predict them? How can we measure warm dense matter? How does WDM transport energy and particles? Can we build understanding from the dense bodies in the cosmos through laboratory experiments and theoretical tools?

- How hot can a laser-produced plasma can become? Can intense photon collisions create dense electron-pair plasmas from vacuum?

- Can we understand trapped antimatter and better understand nature's symmetries? Can full visualization of the dynamics of strongly coupled systems in table-top scale experiments reveal the structure of matter?

Extreme States of Matter and Plasmas

Research Needs

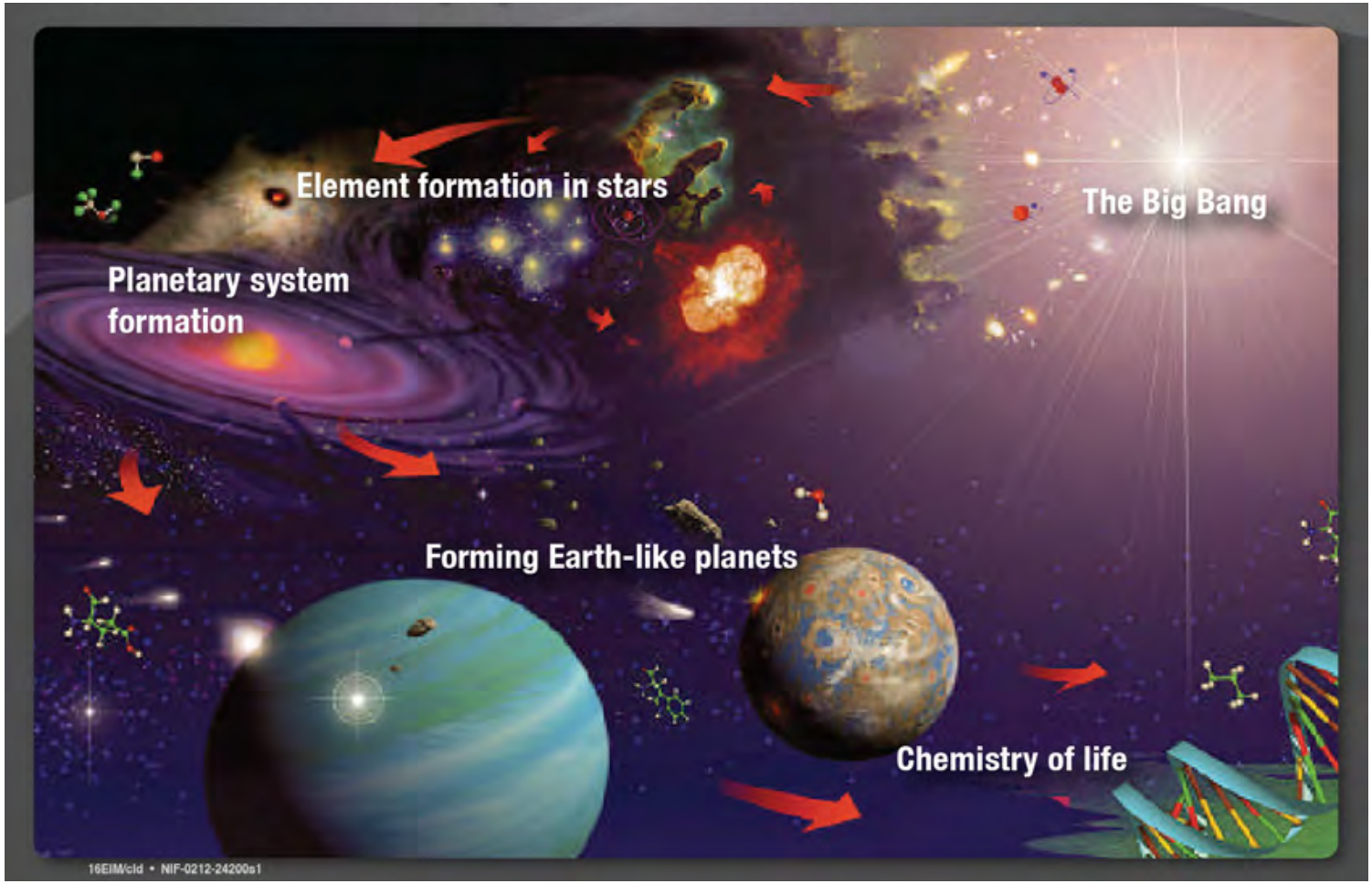
- **WDM Frontier**: (*facilities*) leveraging large-scale flagship facilities (LCLS, NIF, Omega and Z); stand-alone petawatt lasers; ion beam drivers; next-generation ultra-high laser irradiance; … (*theory*) DFT, path-integral PIC; modeling and advanced theory; …

- **HEDP Frontier**: (*facilities*) like WDM; x-ray FELs; high rep-rate multi-PW lasers; … (*theory*) DFT, path-integral PIC; modeling and advanced theory; …

- **Strongly-Coupled Plasma**: (*facilities*) table-top; laser-cooled; mid-range experiments; low-gravity; … (*theory*) micro-; meso-; and macro-scale theory and simulation; …

Understanding the Energetics of the Universe

The Universe is an energetic place: stars, galaxies, explosions, implosions, collisions, shocks, flowing radiant matter, and wound up magnetic fields. Beginning with the massive release of energy of the Big Bang, particles emerge, clouds form, and stars burn brightly to provide the energy that powers the chemistry necessary for life.



Connecting Quarks with the Cosmos, NRC (2003)

Understanding the Energetics of the Universe

- What is the origin of magnetic fields in the universe, from planetary dynamos, to stellar flares and winds, up to galactic jets and relic shocks? And, how do these magnetic fields regulate the transport of heat, particles, and momentum from nature's sources of energy sources, like a stars and galaxies?

- How can laboratory experiments, spacecraft measurements and astronomical observations uncover the fundamental acceleration mechanisms? How do energetic particles modify, and even regulate, their environments? And, what are the power sources and mechanisms for the acceleration of cosmic rays?

- How and why is energy in the universe partitioned into various forms (kinetic, magnetic, turbulent)? And, how does nature couple energy from one form to another, creating extreme particle acceleration in plasmas and beautiful self- organized structures, in apparent defiance of usual thermodynamics?

Understanding the Energetics of the Universe

Common theme unifies these questions: understanding the transformation of energy between forms and across scales…

- Transforming flow to field (*dynamos*)
- Transforming field to flow (*reconnection*)
- Accelerating high energy particles in plasma
- Turbulent cascades and dissipation
- Coherent structures from turbulent flow (*self-organization*)
- Understanding the transport of particles, momentum, and energy through space

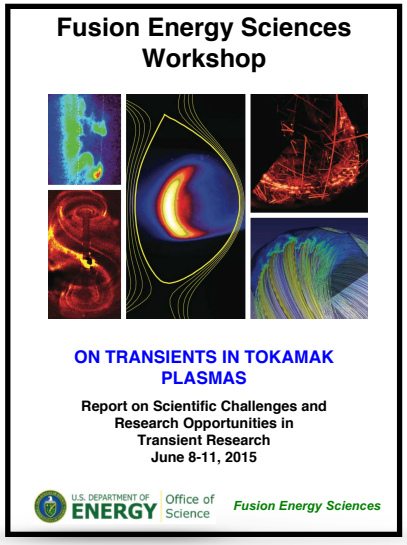
Understanding the Energetics of the Universe

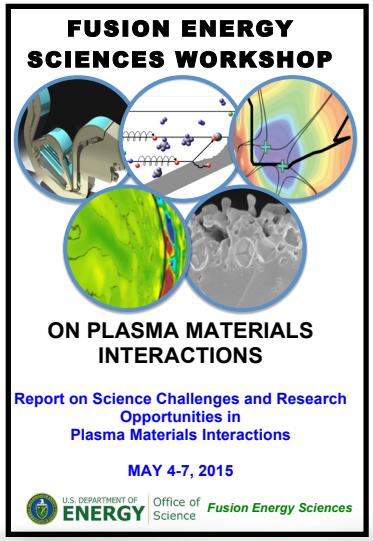
Research Needs

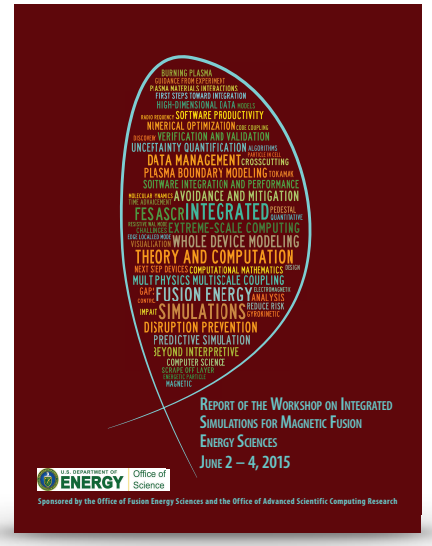
No attempt to specify specific instruments, facilities, or theoretical and computational efforts, but Panel identified research capabilities, tools, and facilities possible for the next decade…

- Multi-field, multi-point, high-bandwidth diagnostics of turbulent phenomena
- Serious validation efforts, especially with sub-grid models and interface dynamics.
- Facilities capable of adjustable parameters, e.g. from collisional conditions to the challenging conditions found in astrophysical and space plasmas.
- Creation and exploration of new regimes in the laboratory
- Spacecraft Instrumentation for turbulent dissipation, EM fields, and plasma velocity distributions.
- A focused effort to apply kinetic theory to understand the turbulence in the weakly collisional space, astrophysical plasmas as well as fusion plasmas.
- Cross-agency research, DOE, NSF, NASA, AFSOR, and ONR, and overlapping mission needs with MFE, IFE, and space and astrophysics communities.

The Frontiers of Plasma Science Are Everywhere in Our Research Programs







Interconnecting our field…