Welcome:
Aims of this Workshop

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Bringing Space Down to Earth Workshop
Basic Plasma Science Facility, UCLA
Westwood, CA
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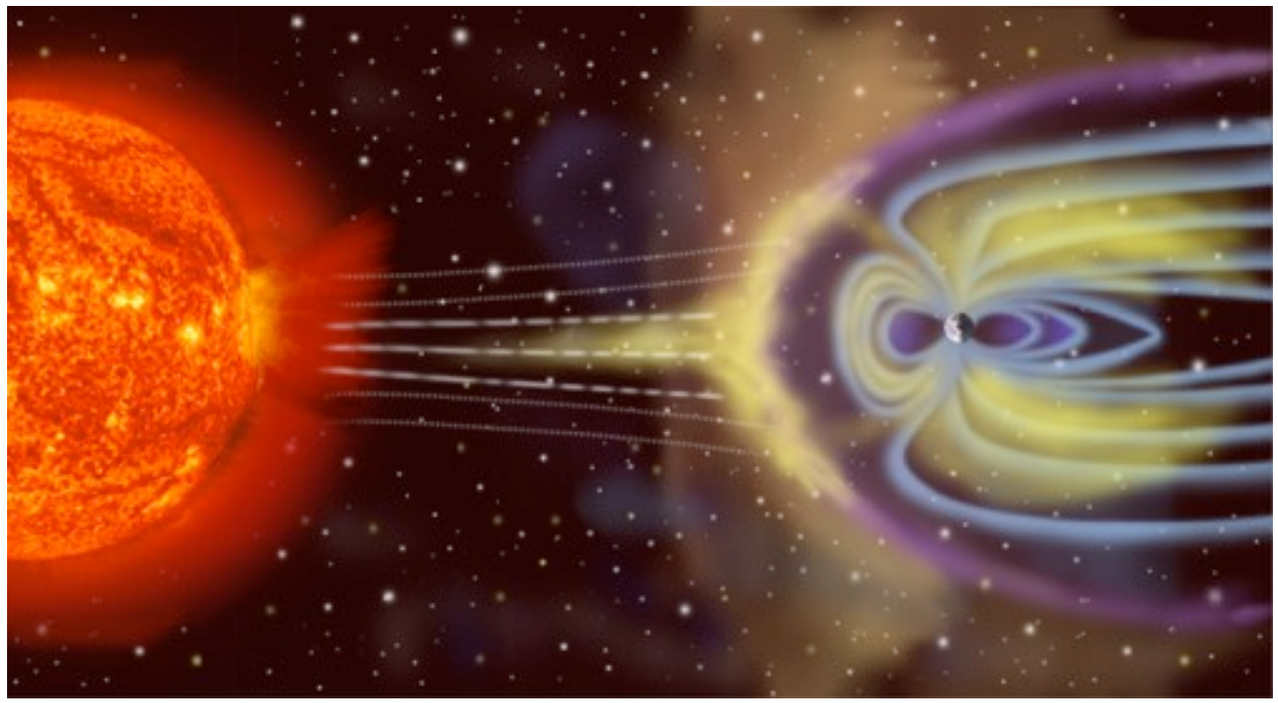
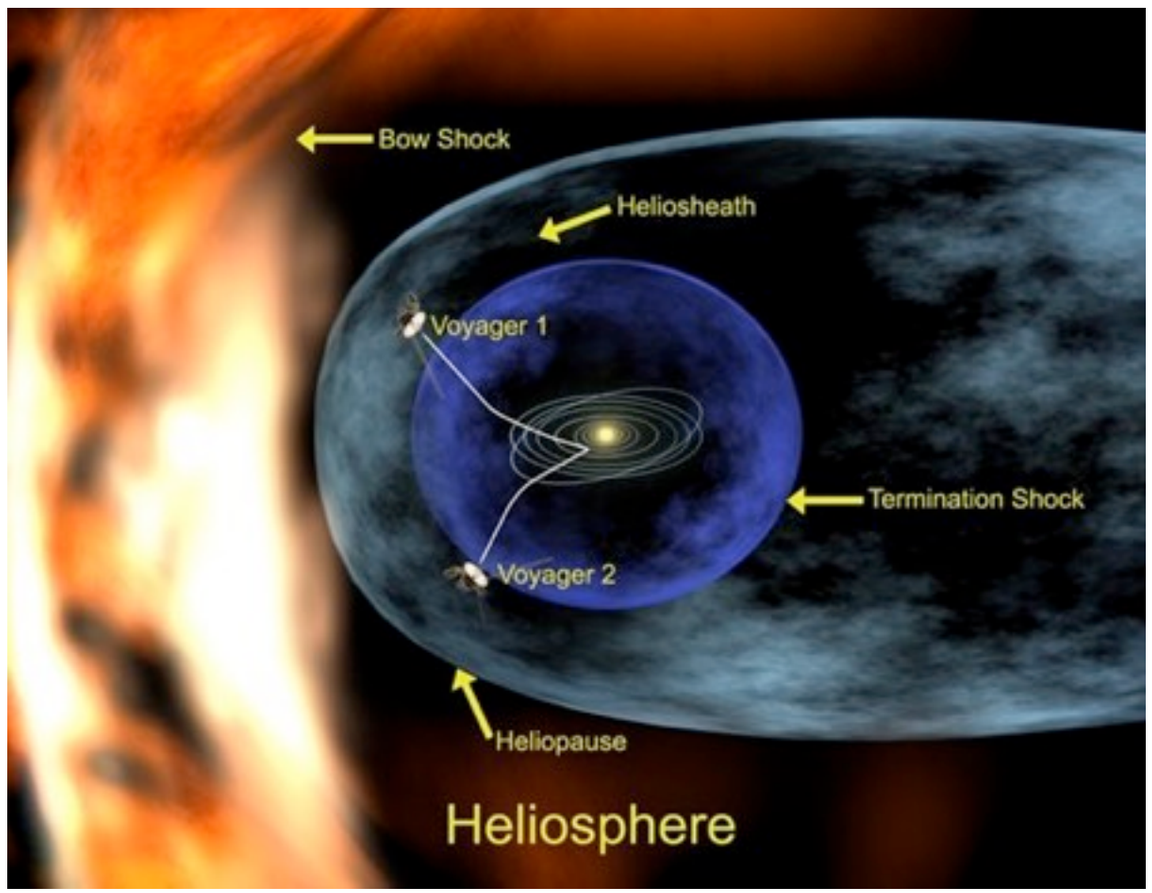
Heliophysics

Heliophysics focuses on exploring the flow of energy from the sun, through interplanetary space, to the magnetospheres of the planets, . . .





. . . and on to the outer boundary of the heliosphere!

Billions of Dollars Fund Spacecraft Missions

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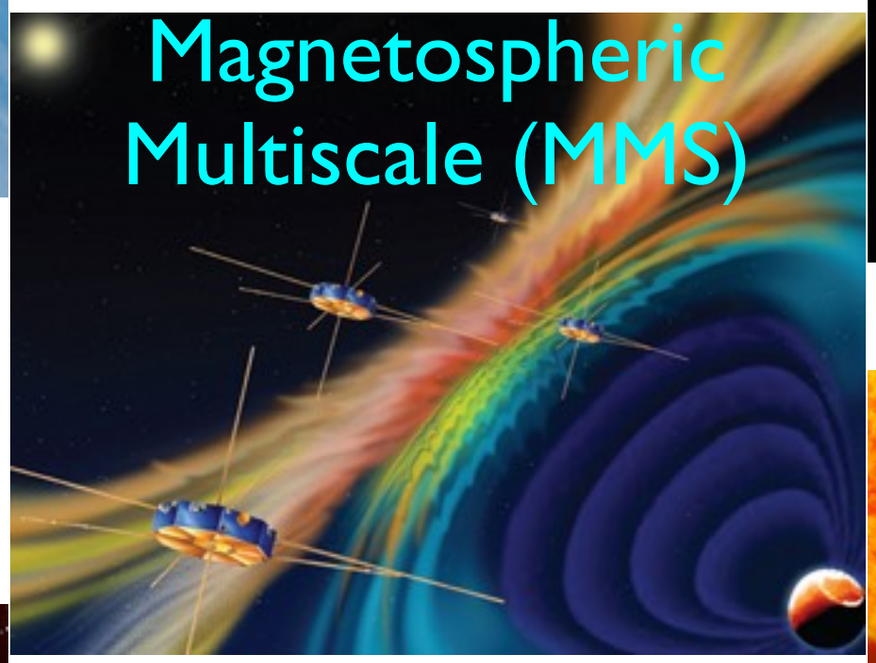

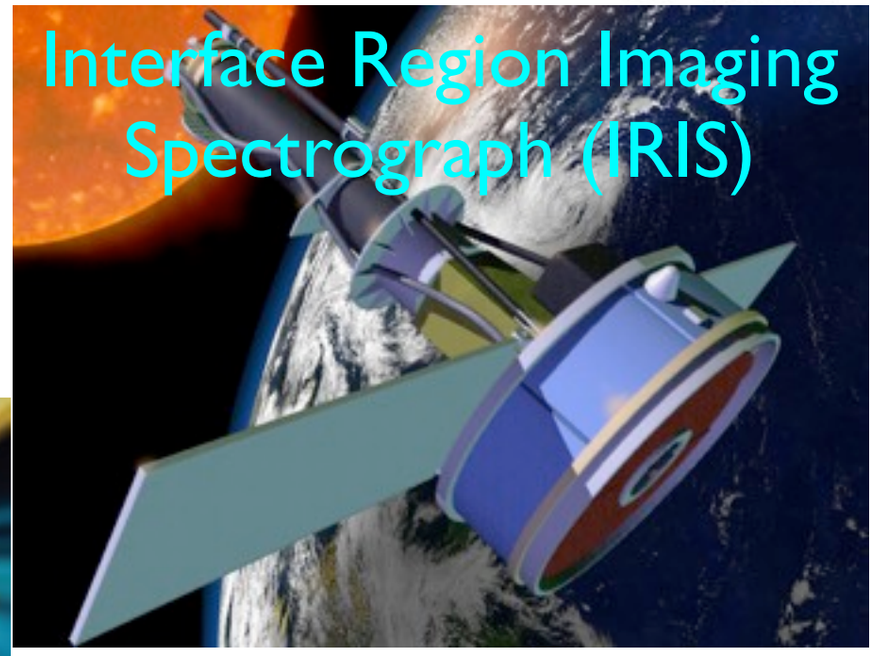

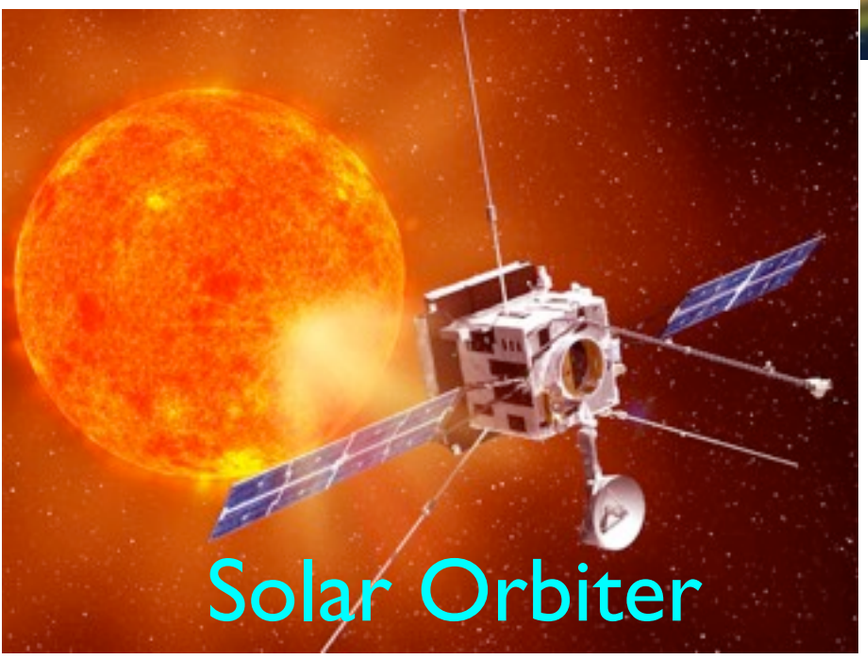

Fundamental Plasma Physics Processes

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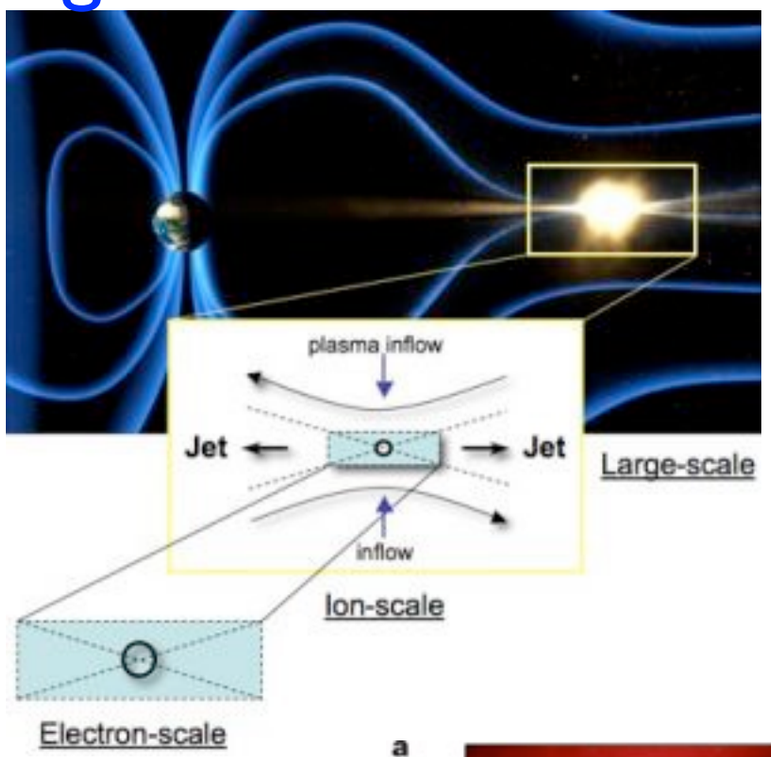
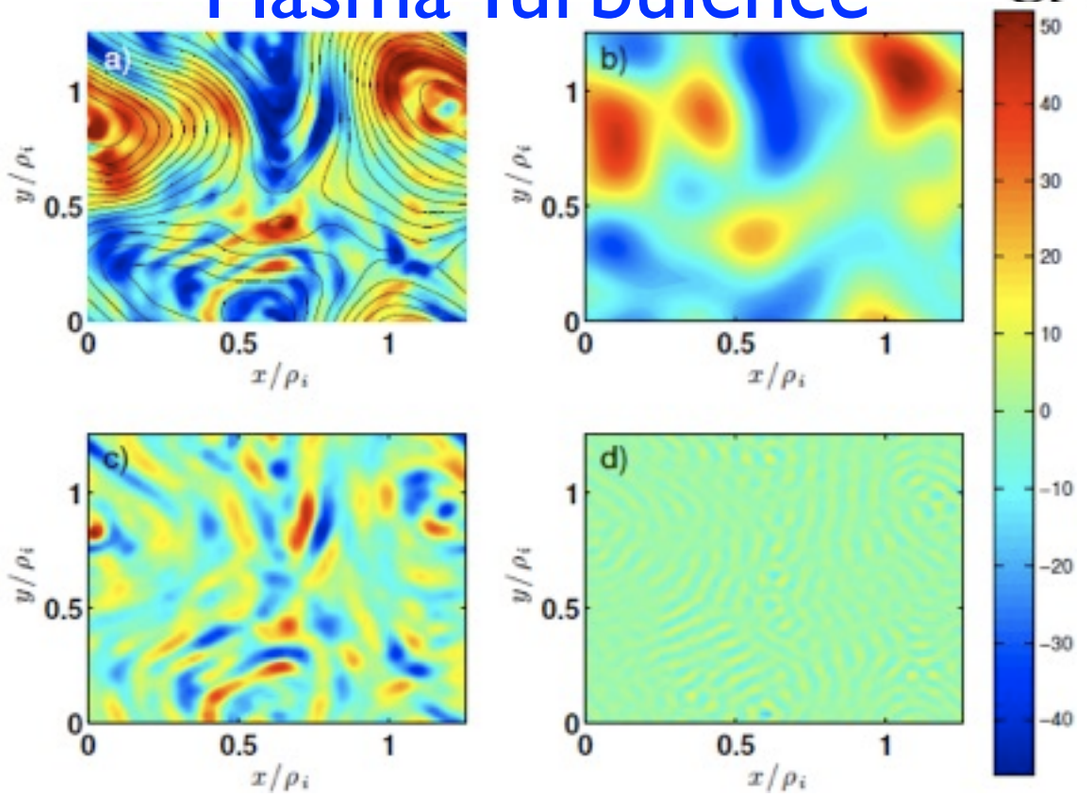
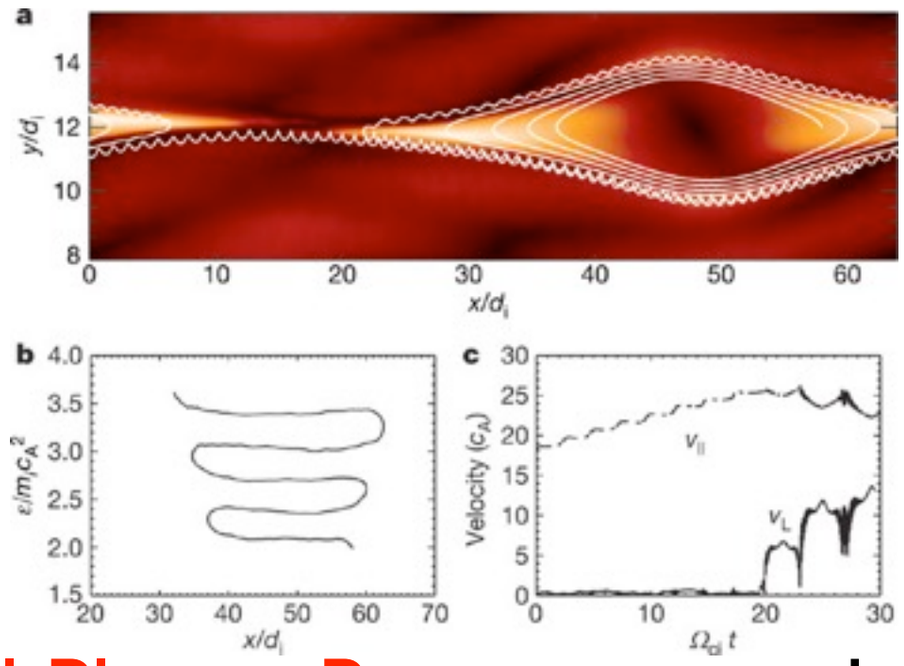
Magnetic Reconnection



Plasma Turbulence



(Howes & TenBarge, 2013)



Energetic Particle Acceleration

(Drake et al. 2006)

Fundamental Plasma Processes are key to progress in **Heliophysics**

Laboratory Experiments are much less expensive than spacecraft!

Space Physics in the Laboratory

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- Fundamental plasma physics
  - Turbulence
  - Magnetic Reconnection
  - Particle Acceleration
  - Instabilities

- Laboratory experiments enable investigations with
  - Controlled conditions
  - Reproducibility
  - Not limited to single-point (or few point) measurements

- Experiments provide a crucial real world complement to
  - Theoretical studies
  - Numerical simulations
  - Spacecraft observations

Bringing Space Down to Earth Workshop

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- Bring together
  - Laboratory Experimentalists
  - Theorists
  - Simulators
  - Spacecraft Instrumentalists

- Map out a strategy for future efforts
  - What new opportunities are on the horizon?
  - Develop new collaborations to utilize fully our existing capabilities and knowledge
  - Collectively prioritize directions for new developments

Goals of the Workshop

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1) To review previous and ongoing efforts to explore the physical processes relevant to space plasmas in the laboratory

2) To identify new opportunities for tackling fundamental space plasma physics problems using current and forthcoming experimental facilities

3) To envision feasible enhancements to existing experimental capabilities that will enable new questions in space plasma physics to be answered

4) To support the ongoing develop of new diagnostic capabilities and novel methods for analysis of laboratory measurements

5) To assess and reinforce the efforts to use numerical simulations as a bridge to connect theoretical concepts to experimental measurements and spacecraft observations

Physics of the Solar Wind Campaign

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- Five Year Renewal of Basic Plasma Science Facility
  - Pursue a new experimental campaign: Physics of the Solar Wind

Workshop Goal:

- Identify several new experiments for Solar Wind Campaign
  - New physics targets for the Large Plasma Device (LAPD)
  - Recruit team members for each collaboration
  - Mixture of theory, simulation, observation, and experiment
  - Drive new proposals to NSF/DOE Program in Plasma Physics

- In discussions throughout the workshop, I hope we can collectively devise and refine new ideas

- Immediately after summary wrap-up, we have time and space for splinter groups to discuss details of proposed new projects

Focus Areas for Workshop Discussions

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- New Experimental Capabilities
- Development and Use of Innovative Diagnostics
- Devising Novel Analysis Techniques
- Using Simulations to Bridge Theory, Observation, and Experiment

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Development of Experimental Capabilities

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- New experimental capabilities enable us to explore the fundamental space plasma physics of different environments

- The plasma parameters influence which physical mechanisms contribute to the evolution

Plasma Parameter Dependence

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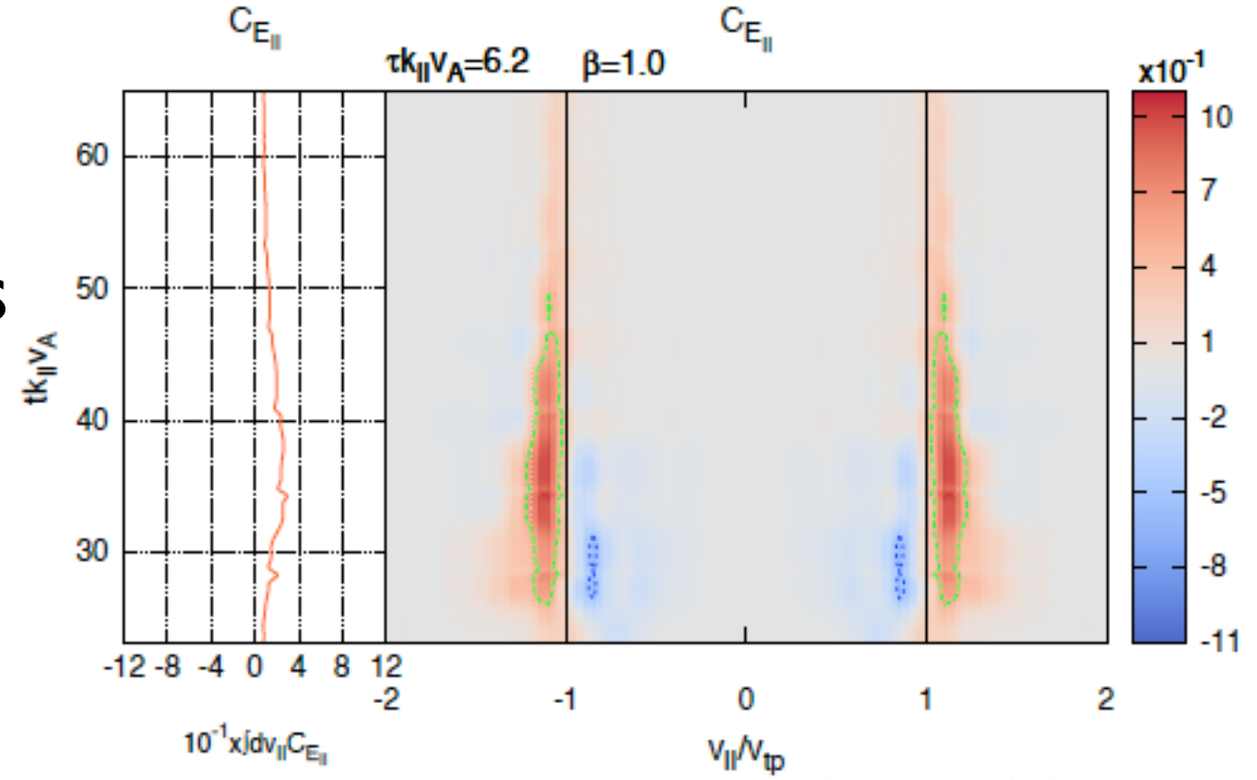
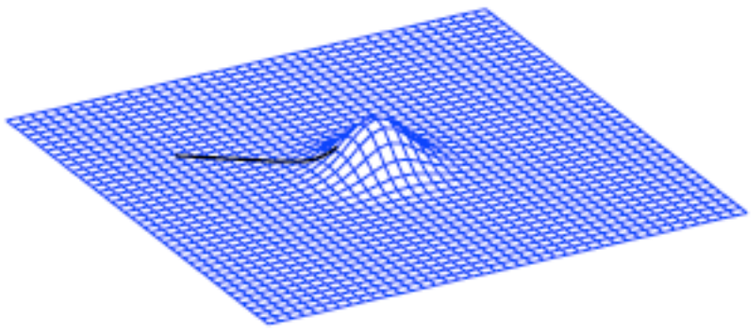
Example: The energization of ions by dissipation of turbulence

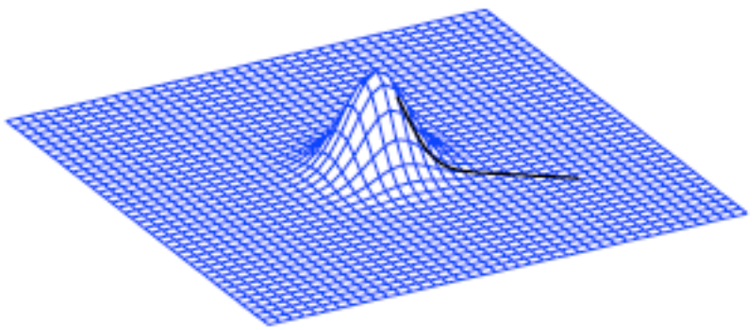
- The plasma beta, $\beta = \dfrac{8\pi nT}{B^2}$, determines which mechanisms play a dominant role

- At $\beta \sim 1$, ion Landau and transit-time damping is an effective process for removing turbulent energy



(Howes, McCubbin, & Klein, 2017)





(Chandran *et al*. 2010)

- At $\beta \ll 1$, ions are way out of resonance, so Landau and transit-time damping are weak. But for finite amplitude fluctuations, stochastic ion heating may be significant

Development of Experimental Capabilities

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- What are the key parameter regimes for different space physics environments and problems?

Parameters:

Plasma beta $\beta = \dfrac{8\pi n T}{B^2}$

Collisionality $\dfrac{\nu}{\omega}$

Temperature ratio $\dfrac{T_i}{T_e}$

Length scales $\dfrac{\rho_i}{L}$, $\dfrac{\rho_e}{L}$

Time scales $\dfrac{\omega}{\omega_{pe}}$, $\dfrac{\omega}{\Omega_i}$

Amplitude $\dfrac{\delta B}{B}$

- What laboratory facilities can access these different regimes?

  - Plasma confinement means low beta $\beta \ll 1$ is easier to achieve in the lab (relevant to solar corona)

  - Obtaining $\beta \sim 1$ plasmas in the lab is more difficult (relevant to near-Earth solar wind)

Development of Experimental Capabilities

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Key Questions to answer at this workshop:

- What are the new capabilities that we have in the lab?

- How can we best utilize those capabilities to explore poorly understood processes in space plasmas?

- Are their potential upgrades to existing facilities that will enable us to access new regimes that are rarely explored experimentally?

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Innovative Diagnostics

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An important consideration in designing experiments is . . .

What quantities we can measure?

Developing sophisticated diagnostics may enable new investigations

- What measurements can be made in the laboratory that are difficult to make in space, and vice versa?

- Multipoint measurements are difficult in space (require costly additional spacecraft), but are relatively easy to make in the lab

- 3D velocity distribution functions are routinely measured in space, but are difficult to obtain in the lab

Innovative Diagnostics

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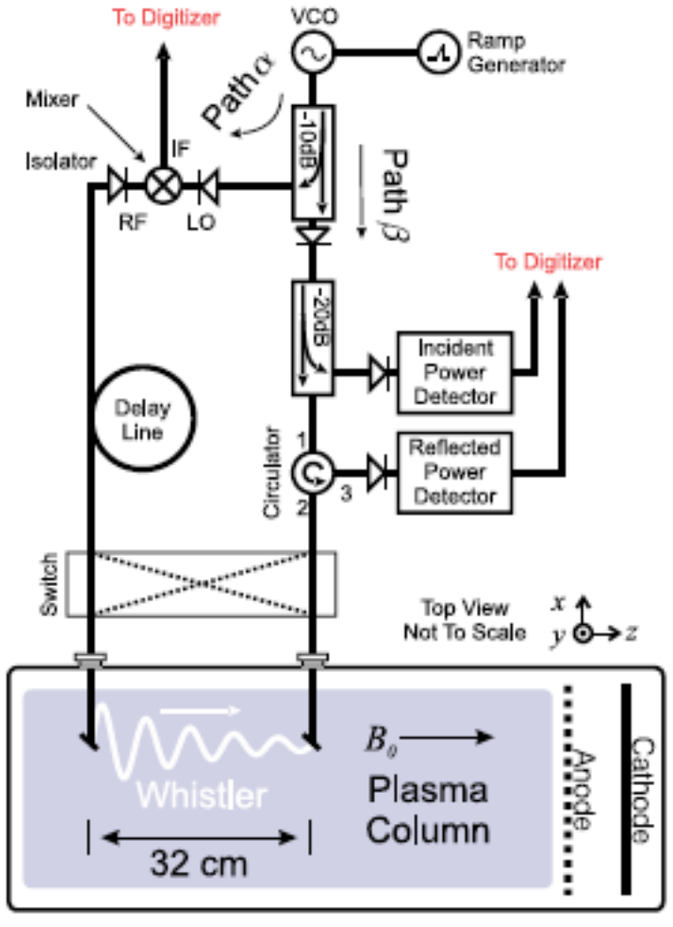
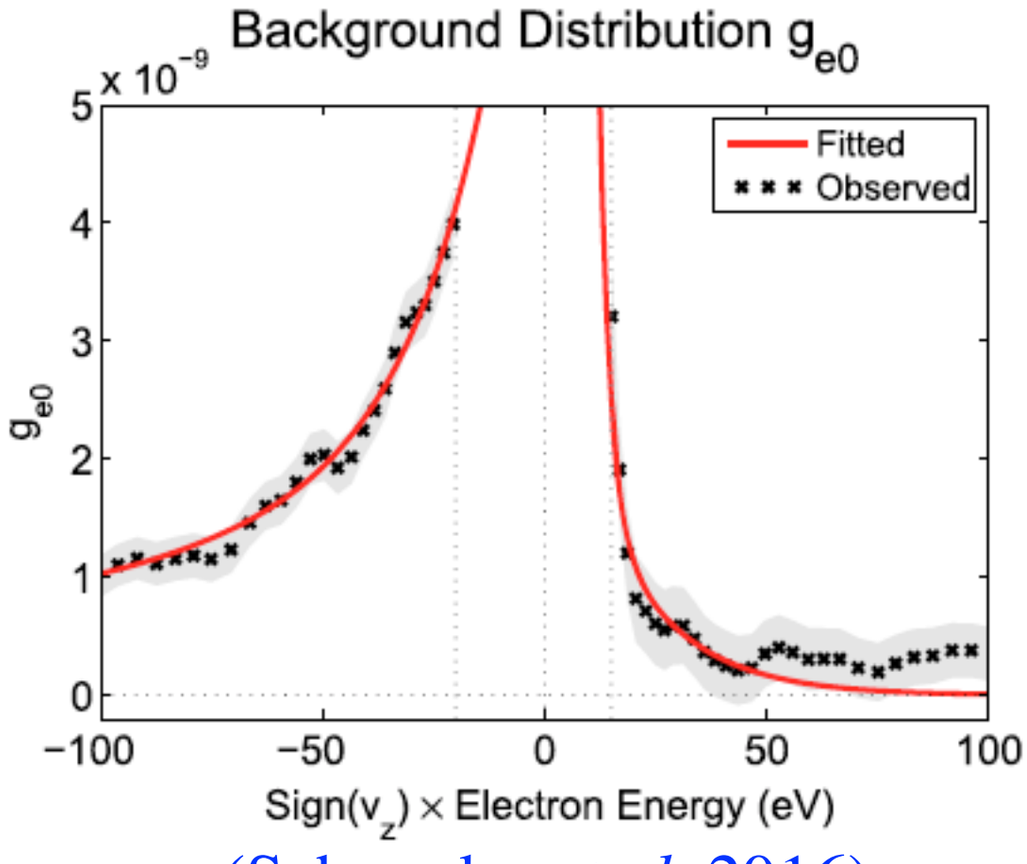
- Can we identify new diagnostic capabilities that can open up new avenues of investigation?



Example: Whistler Wave Absorption Diagnostic

(Thuecks, Skiff, & Kletzing, 2012; Schroeder *et al*. 2017)



(Schroeder *et al*. 2016)

$T_e \sim 2$ eV

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Novel Analysis Techniques

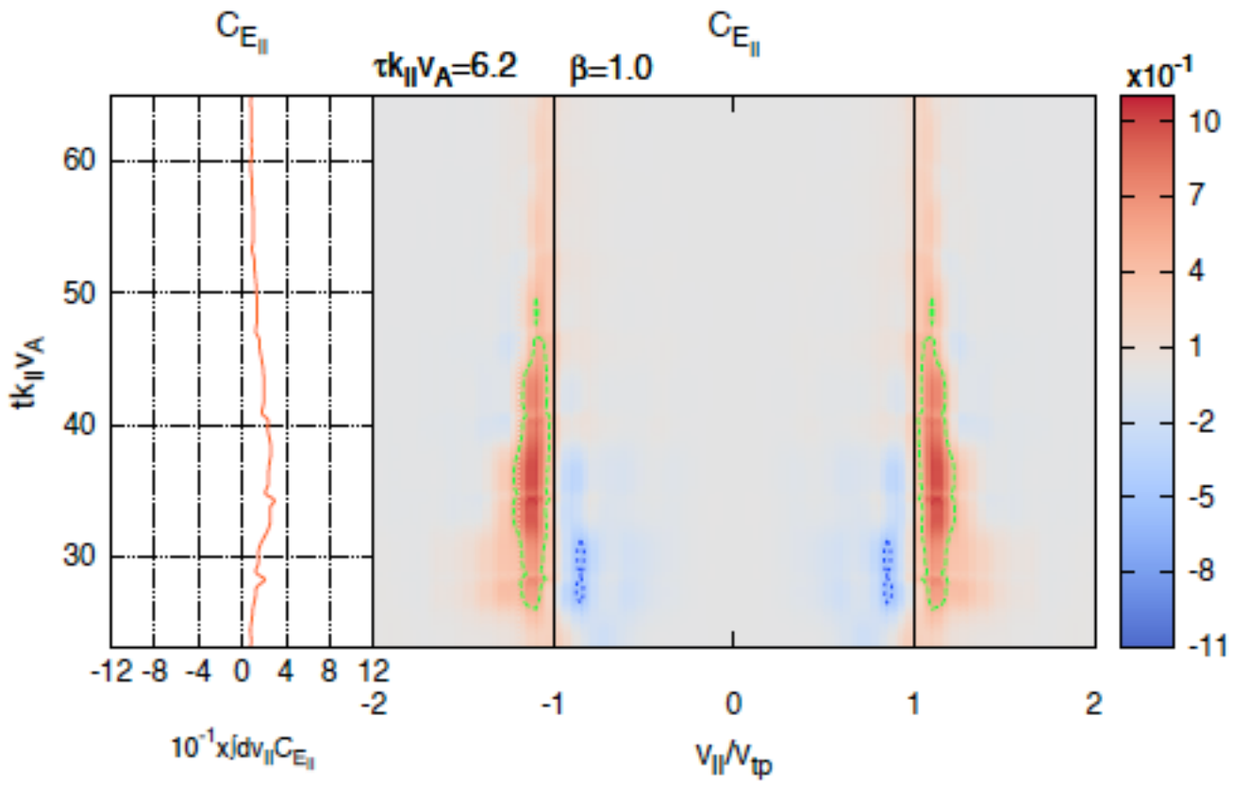
- Can new analysis methods enable us to exploit fully measurements made in laboratory experiments?

Example: Field-Particle Correlations

- Single-point measurements of fields and velocity distributions can be used to determine particle energization

- Correlate $E_\parallel(\mathbf{r}_0,t)$ and $f_s(\mathbf{r}_0,\mathbf{v},t)$ measurements

$$C_{E_\parallel}\left(-q_s\frac{v_\parallel^2}{2}\frac{\partial f_s(\mathbf{r}_0,\mathbf{v},t)}{\partial v_\parallel},E_\parallel(\mathbf{r}_0,t)\right)$$



(Howes, McCubbin, & Klein, 2017)

Focus Areas for Workshop Discussions

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Supporting Numerical Simulations

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- Numerical simulations provide a valuable resource to:
  - Design experiments
  - Interpret laboratory measurements and spacecraft observations
  - Establish connections between idealized theoretical models and the messy reality of lab and space plasmas

Supporting Numerical Simulations

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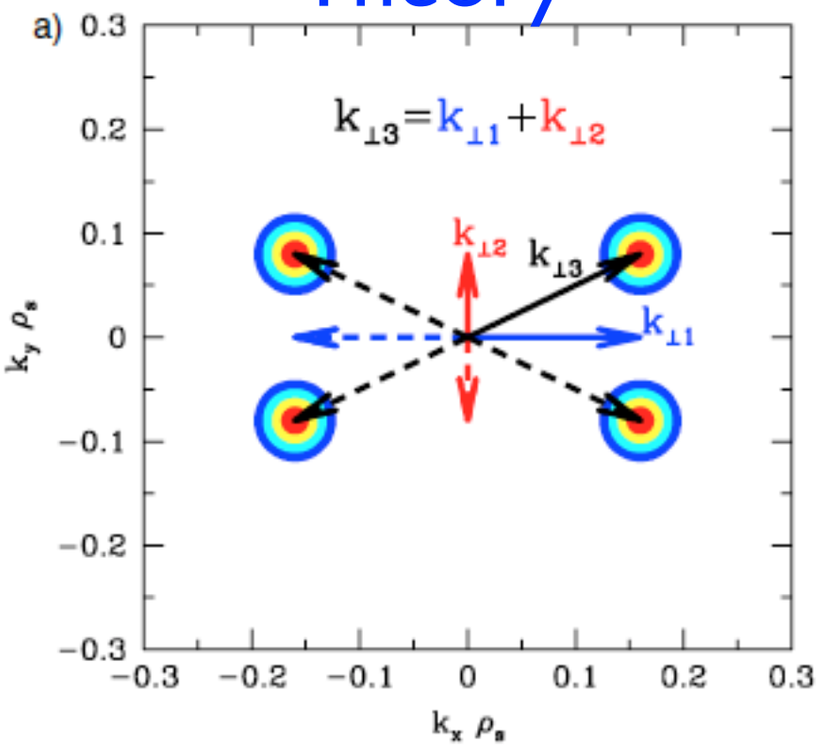
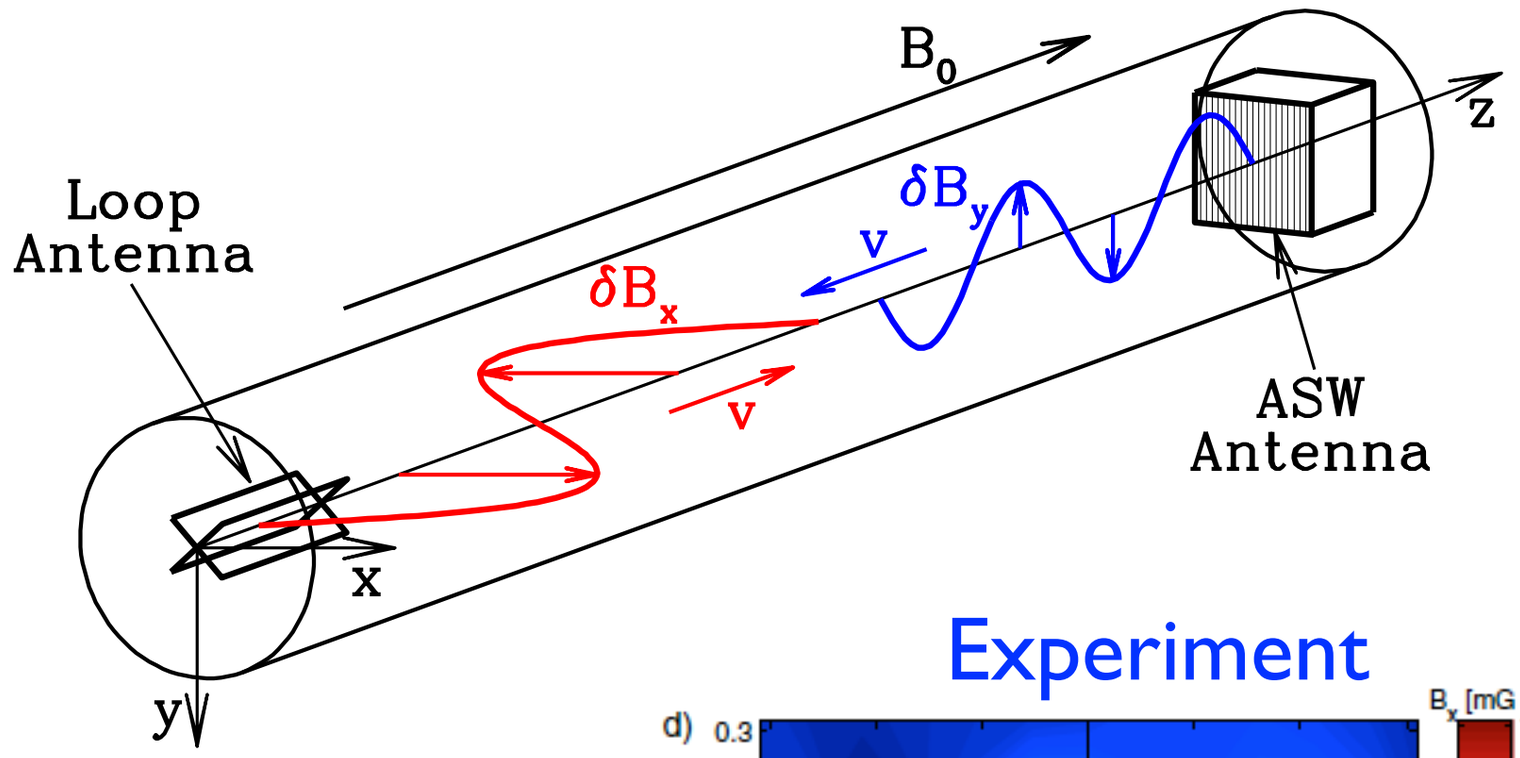
Example: Alfven Wave Collision Experiments

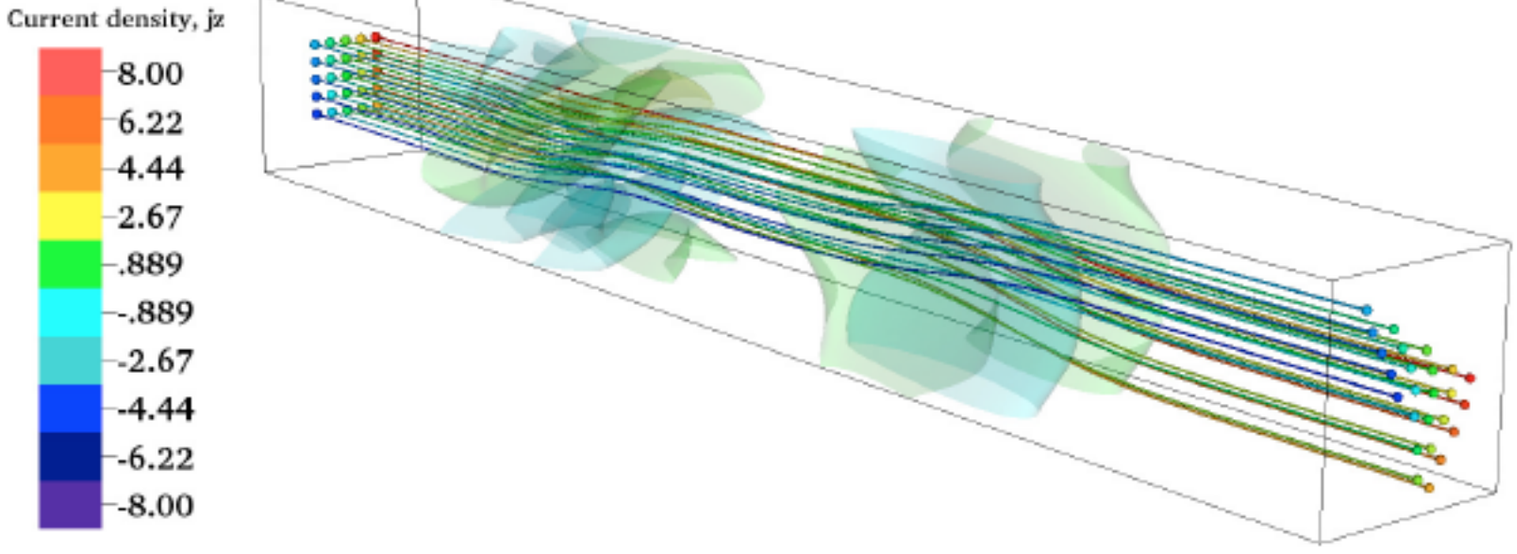
Theory



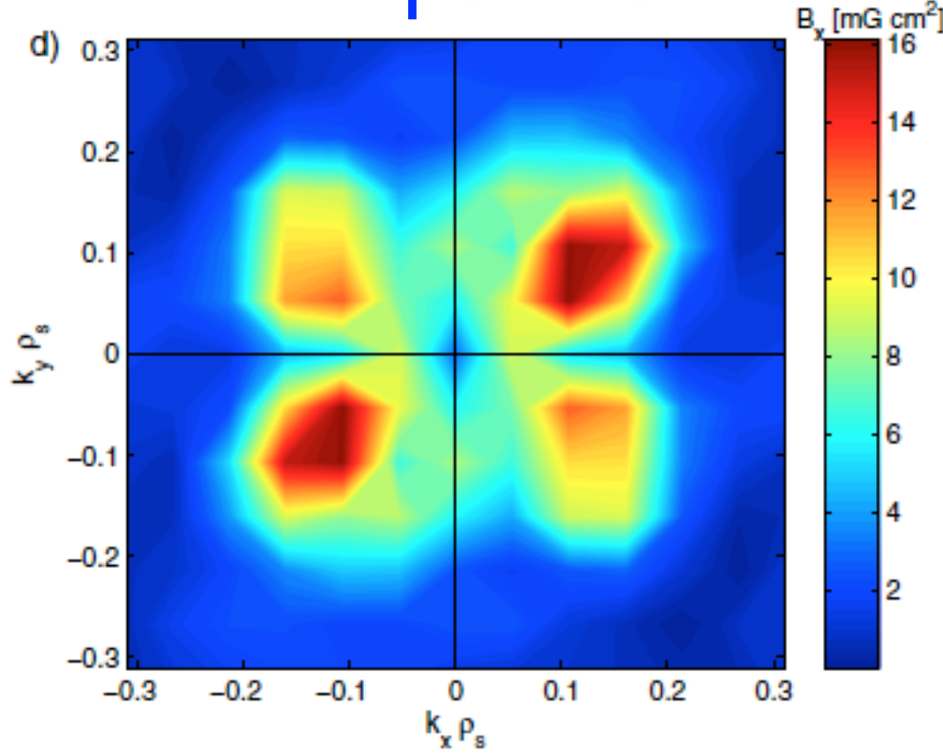
Experimental Design



Simulation



Experiment



Space Science Reviews

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• Pursuing the possibility of publishing the findings of this workshop in Space Science Reviews

Outline:

I. Importance of the Laboratory Investigation of Space Physics
II. Brief Review of Previous Space Physics Successes in the Laboratory
III. Current Facilities and Capabilities, highlighting relevance to specific space environments
IV. What's on the Horizon?
  A. Innovative Diagnostic Capabilities
  B. Novel Analysis Techniques
  C. Cutting-edge Simulation Capabilities
V. Highlight in detail how laboratory investigations can complement modern spacecraft measurements
VI. Future efforts on the near horizon: Strategic directions to pursue

• Any contributions from workshop participants are welcome, and I may solicit some material from you later

Thank you for coming

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Comments?

Questions?

A Synergistic Approach to Space Physics

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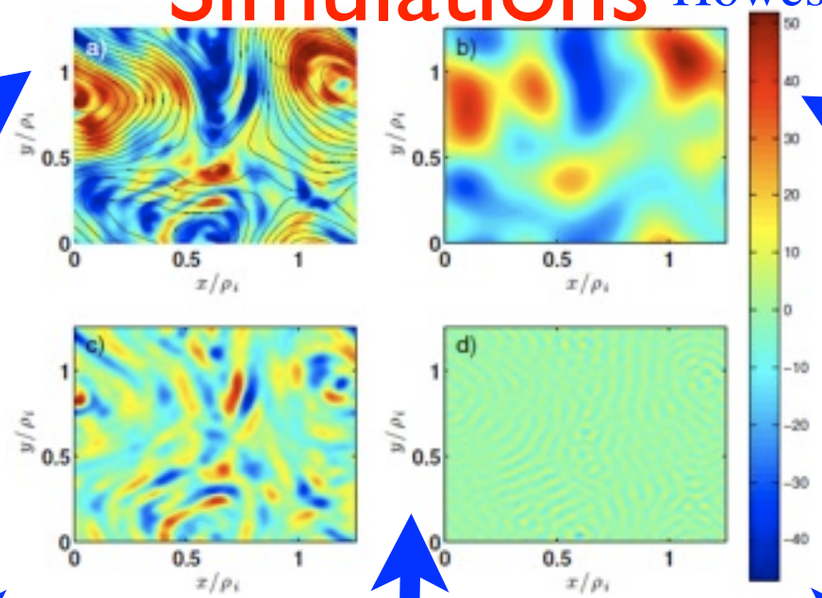
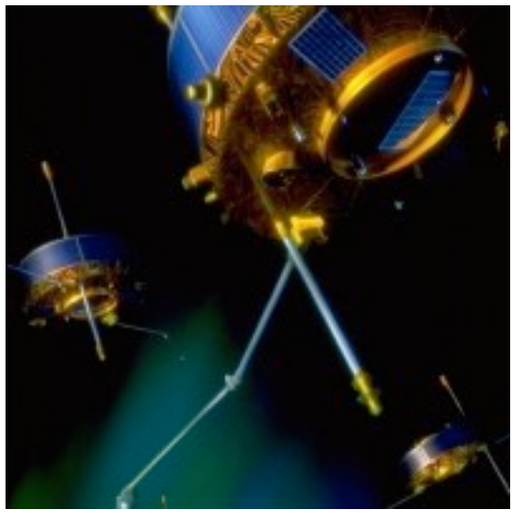
Simulations

Howes & TenBarge, 2013



Observations

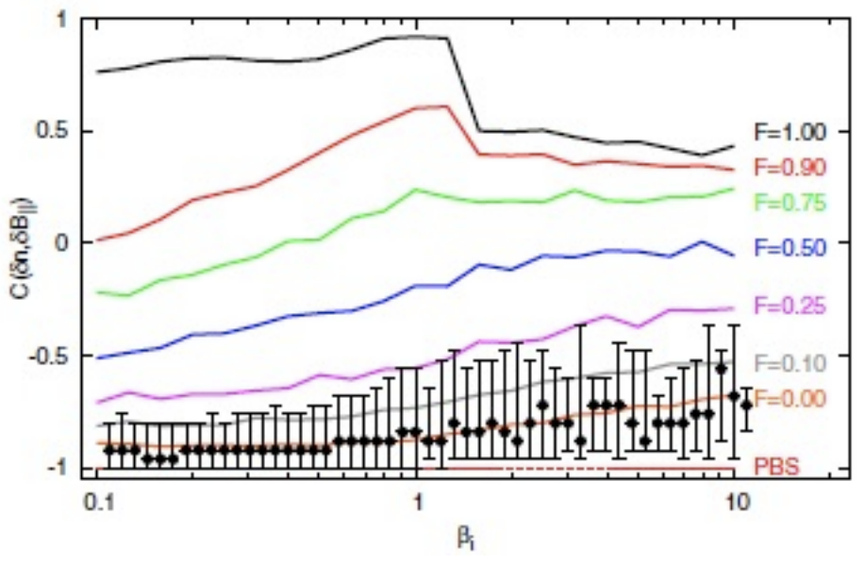


Cluster spacecraft

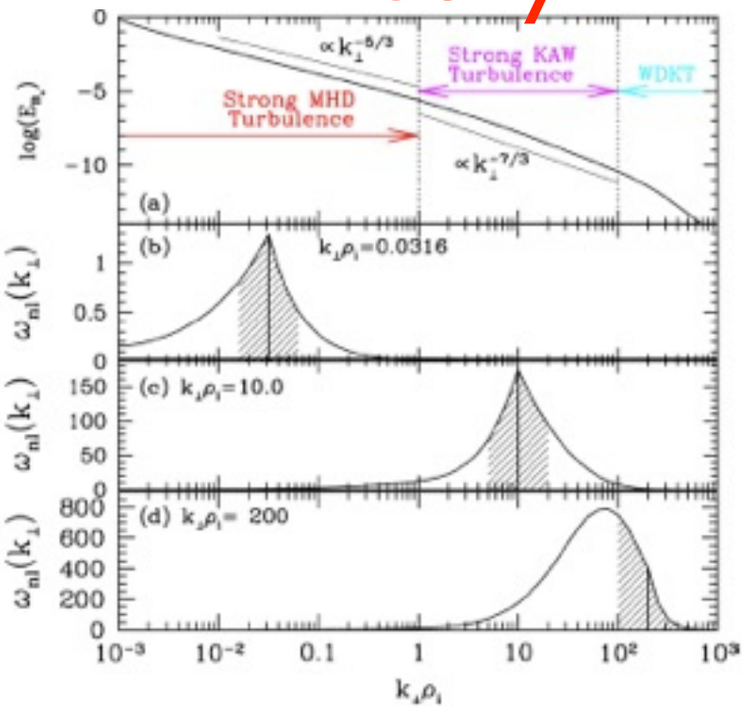
Experiments

LArge Plasma Device (LAPD), UCLA

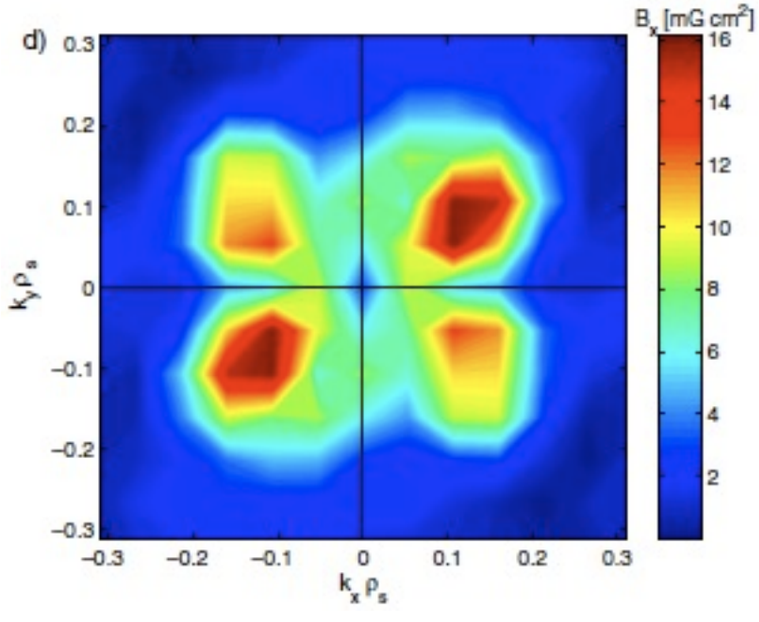
Theory



Howes, et al. 2012



Howes, TenBarge, & Dorland 2011



Howes et al., 2012