

Session #18: The kinetic physics of collisionless shock waves in the heliosphere

Science Questions

- How is energy dissipated/transferred at collisionless shocks through self-generated kinetic plasma mechanisms?
- How do these kinetic mechanisms depend on the local plasma environment throughout the heliosphere?
- How well can we address these questions with current and upcoming missions?

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Theory

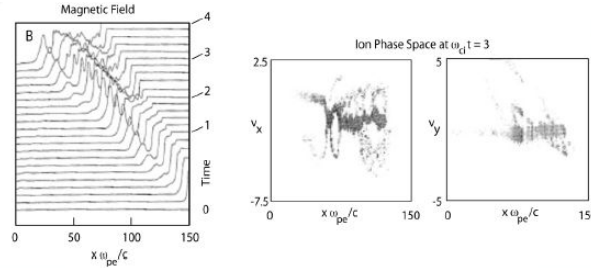
Jimmy Juno, PPPL

Examine energy transfer with numerical simulations

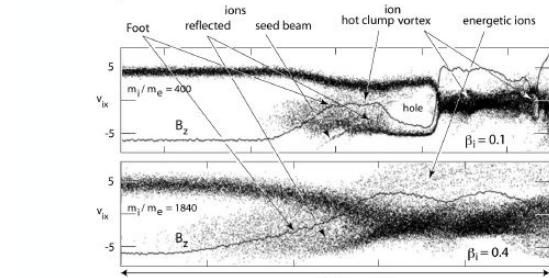
The answer to dissipation is found in phase space

Phase space evolution is complicated to describe numerically, continuous effort through the years

2020: Direct numerical treatment of Vlasov equations



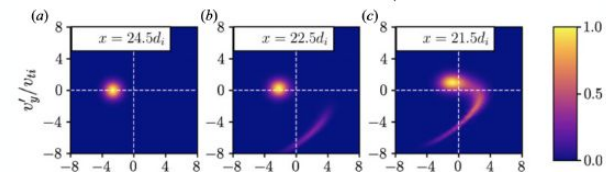
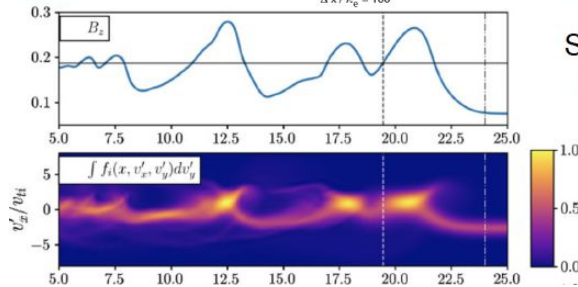
Biskamp & Welter JGR 1972
(Adapted from Balogh & Treumann 2013)



Scholer *et al.* JGR 2003
(Adapted from Balogh & Treumann 2013)
more particles = more structure
can even do realistic mass ratios!

Juno *et al.* JPP 2020
Noise-free distribution functions
with grid-based methods!
See Juno *et al.* JCP 2018, Hakim & Juno Supercomputing 2020

Increasing computing power
New algorithms



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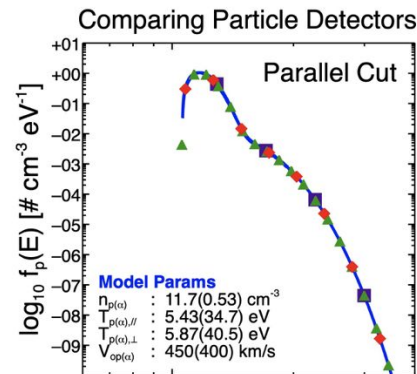
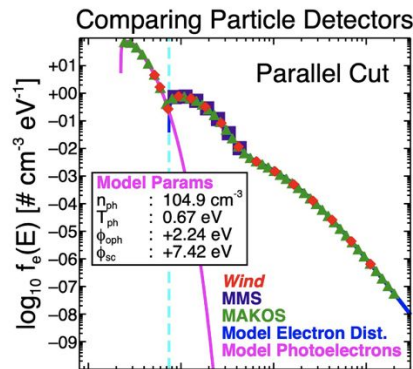
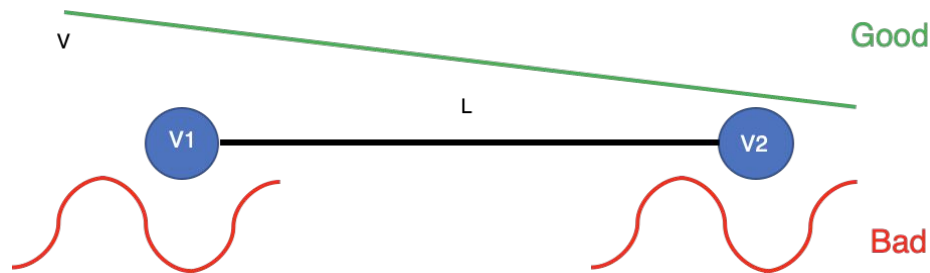
Observations

Katy Goodrich, West Virginia University

Accurate **measurement of large-amplitude, high-frequency waves** is key to understanding dissipation in shocks

Plasma **measurements optimized for bow-shock populations** are necessary

MMS fairly limited in capability beyond magnetosheath



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Observations

MAKOS: a space mission dedicated to shock physics



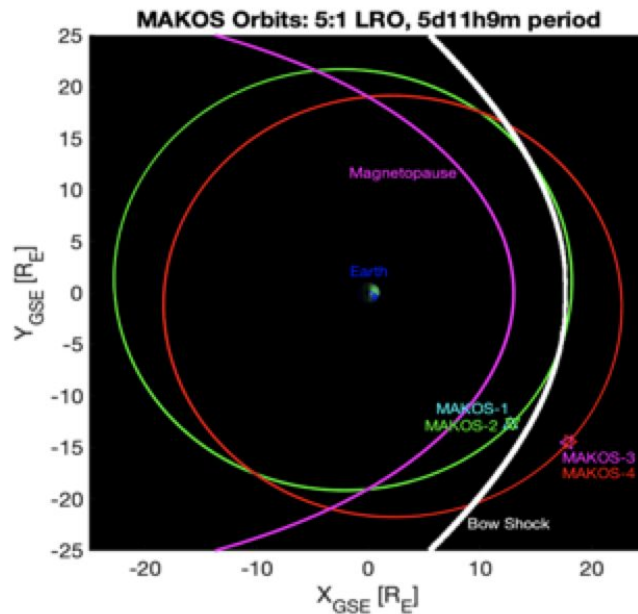
1. *What is the energy budget on either side of a collisionless shock?*

- Measure all dominant forms of energy upstream and downstream of the bow shock
- Upstream and downstream measurements taken simultaneously from at least two spacecraft

2. *What are the processes governing energy conversion at & within collisionless shocks?*

- Observe electromagnetic fields and particle populations within the shock layer

3. *How & why do these processes vary with shock orientation and driving conditions?*

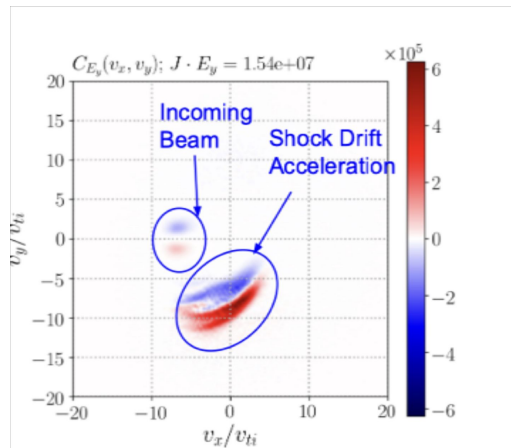


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Discussion

Different novel dissipation measurements were discussed to identify phase space energization, including field particle correlations, and kinetic entropy (HORNET)

- Links with laboratory plasma experiments
- Importance of accurate description of VDF
- Extend observations to other heliospheric environments such as the near-sun HCS



Simulations of Field Particle Correlations of Shock Ripple In Hybrid Simulations

Novel kinetic entropy diagnostic and measurement proposed from Cassak and Barbhuiya

$$\frac{s_{\sigma} V_{rel}}{n_{\sigma}} = -k_B \int \frac{f_{\sigma}}{n_{\sigma}} \ln \left(\frac{f_{\sigma}}{f_{\sigma M}} \right) d^3 v$$

