Magnetic Reconnection (Nuno's 2018 prerecorded SULI lecture)

Remembering Prof. Nuno Loureiro (1977-2025)

Herman Feshbach Professor of Physics and of Nuclear Engineering and Science at MIT

Former Director of MIT Plasma Science and Fusion center

Scientific contribution in research areas including:

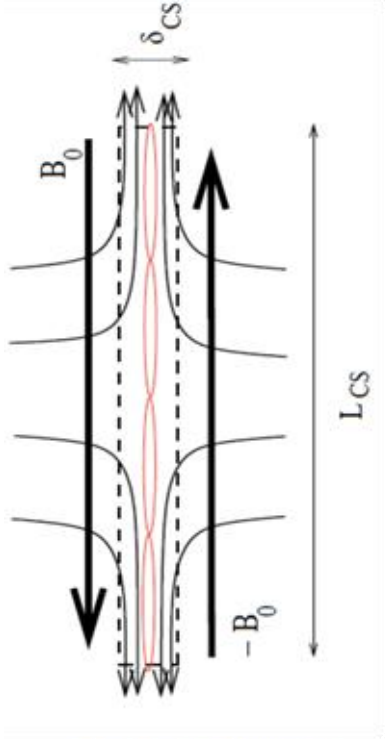
Fundamental Plasma Processes: Magnetic reconnection, plasma turbulence, plasma instabilities

Magnetically confined fusion: transport of Alpha Particles

Quantum computing for plasma physics

Machine learning for fusion and plasma physics 0

Magnetic Reconnection in the Plasmoid regime



Credit: N. Loureiro

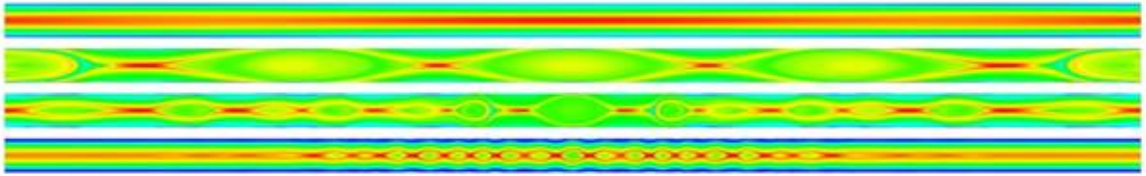
Loureiro et al. 2007, 2013 performed the first calculation of tearing modes on a SP-current-type of configuration:

$$\gamma_{\max}\tau_A \sim S^{1/4}$$

$$k_{\max}L_{CS} \sim S^{3/8}$$

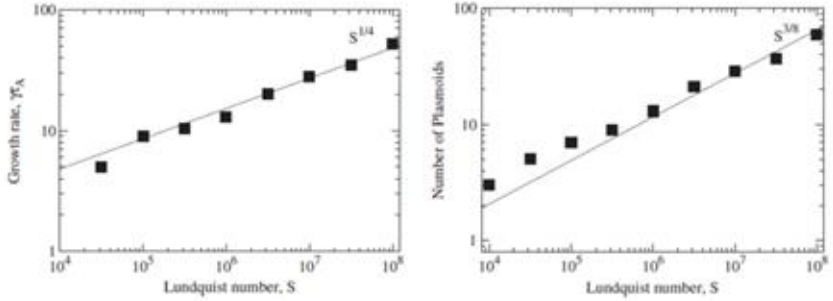
Threshold for the instability: $S \geq 10^4$

[Loureiro+ 2007]

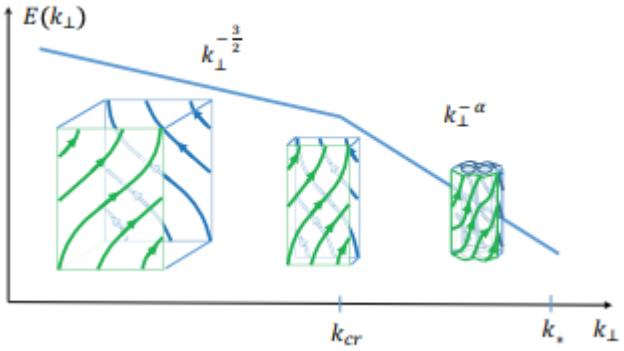


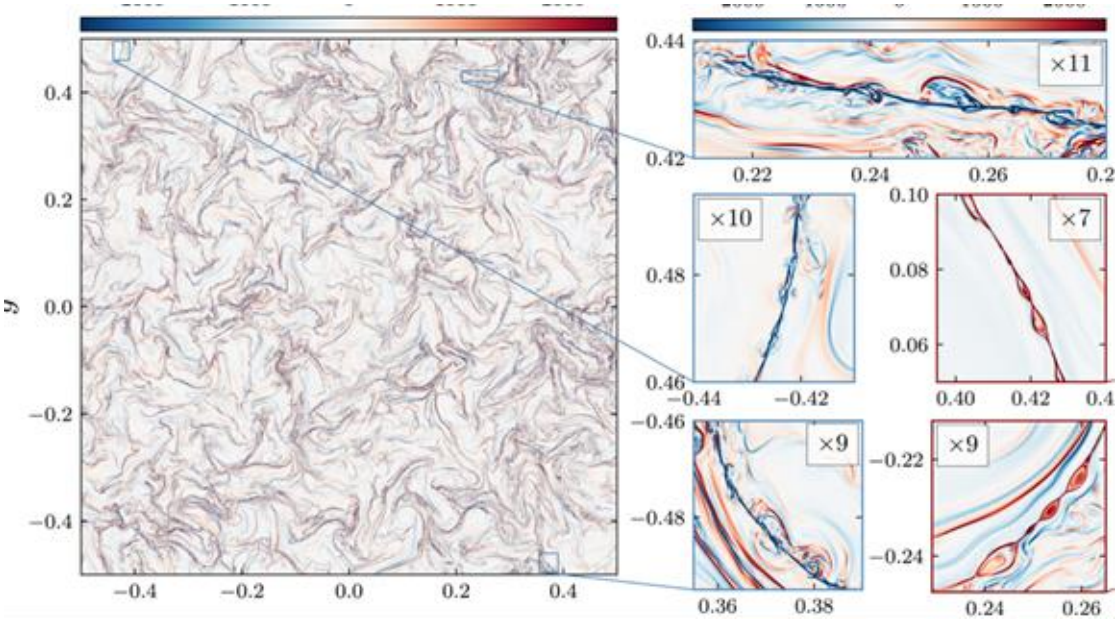
As S increases (from top to bottom, $S = 10^4, 10^5, 10^6, 10^7$), the number of plasmoids and their growth rate increase.

[Samtaney et al. 2009]



Interplay between reconnection and turbulence





Theory: **Loureiro** & Boldyrev 2017, 2018; Anisotropic turbulent eddies become unstable to tearing instabilities and turbulence becomes reconnection-mediated.

See also Mallet & Schekochihin 2017,2019; Simulation: Dong+2018, 2022

Broader research directions

Quantum computing for plasma physics

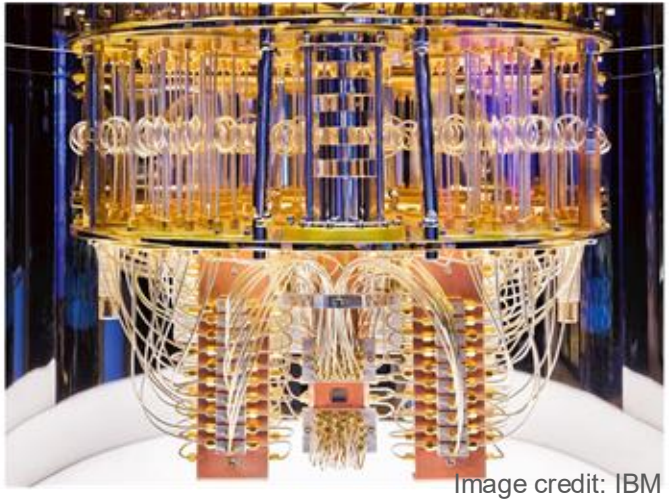
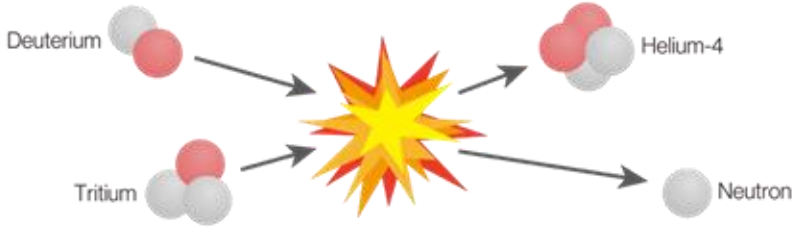


Image credit: IBM

- Quantum computers can solve <u>some</u> problems far faster than their classical counterparts
- The challenge: developing quantum-compatible algorithms for the highly nonlinear equations relevant to plasma physics

Alpha particle confinement and instabilities



- Confining energetic α-particles is essential for a self-sustaining fusion plasma ("burning plasma")
- But, α-particles can drive instabilities that eject them prematurely and degrade overall confinement

Other topics including…

- Machine learning for discovering reduced models of plasma dynamics (data-driven closures)
- Parametric decay instabilities of lower-hybrid waves for RF current-drive

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B.S. at Zhejiang University (China); PhD at MIT (under the supervision of Prof. Loureiro); Postdoc at Institute for Advanced Study/Princeton university

Interested in PhD in plasma physics, turbulence and magnetic reconnection?

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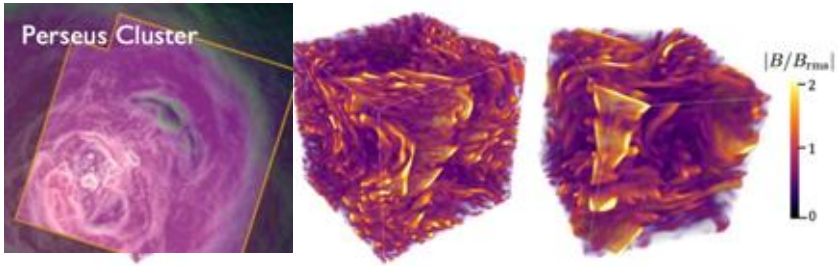
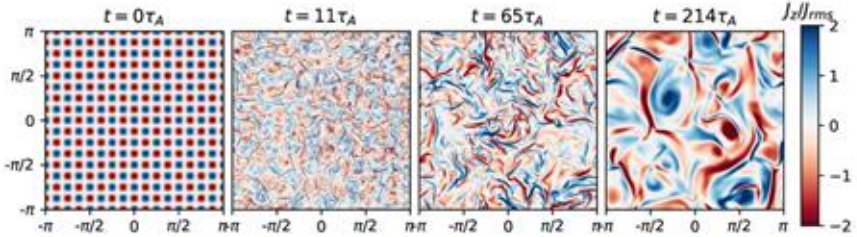
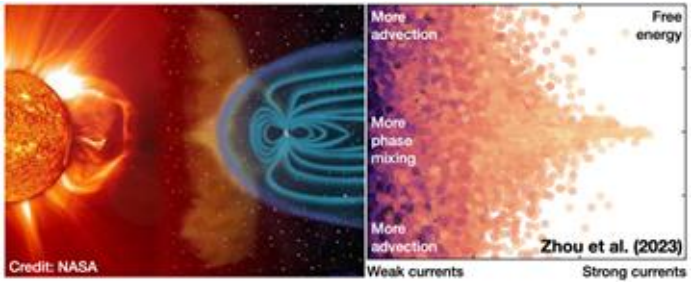
Origin of cosmic magnetic fields: magnetogenesis and turbulent dynamo



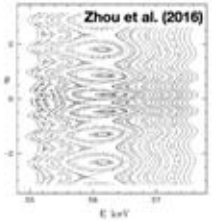
Reconnection-controlled decaying turbulence

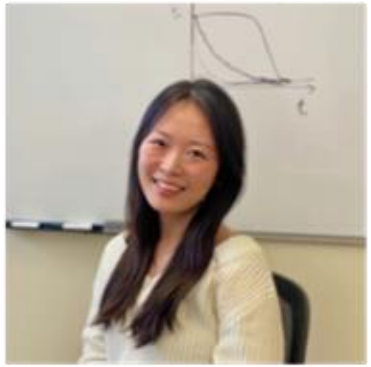


Phase-space dynamics of kinetic turbulence – Particle heating in the solar wind.



Controlled nuclear fusion





About Me

Suying Jin – Current Postdoctoral Associate at MIT Plasma Science and Fusion Center, Ph.D. in Plasma Physics from Princeton University (2025), B.S. in Physics from UCLA (2018)

Research interests: nonlinear wave phenomena, wave-particle interactions, phase space methods for wave dynamics, RF heating and current drive

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