PRINCETON PLASMA PHYSICS LABORATORY

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Princeton Plasma Physics Laboratory

Oct. 20, 2021

DOE Distinguished Scientist Fellows Awards Ceremony

A taste of our research on fusion energy, & thanks to my students and colleagues.

(in 3 minutes ☺)

Slides & high-rez video at https://w3.pppl.gov/~hammett/talks/

Exciting times in fusion energy research

Fusion energy is hard, and a lot remains to make it a reality, but we are making a lot of progress and there are interesting ideas that could significantly reduce the cost of fusion and make it more practical

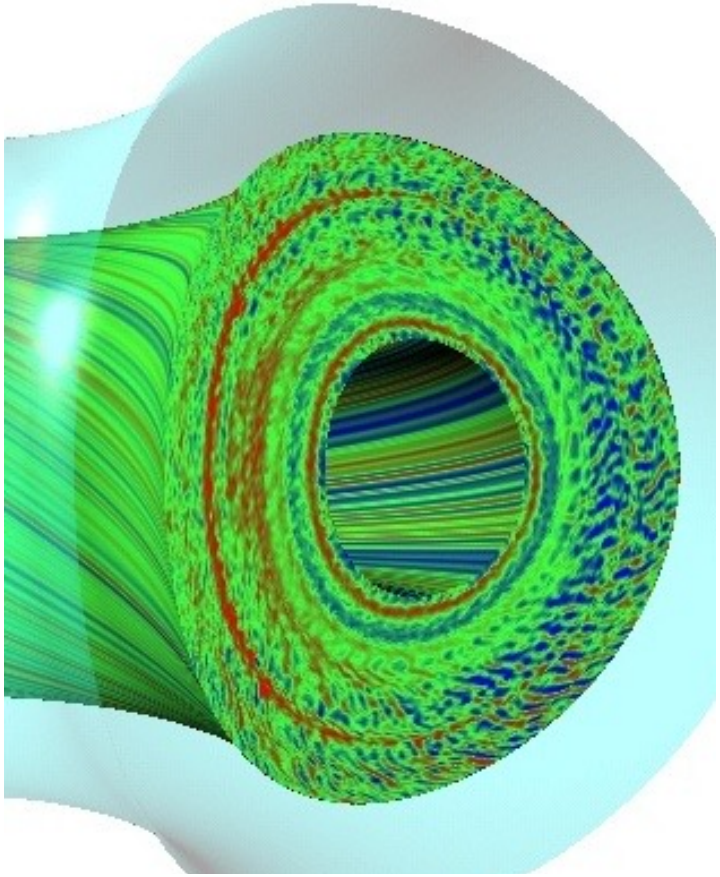
We need to pursue multiple strategies to deal with climate change:
Fusion is one of the few long-term options that can provide a reliable energy source to balance the intermittency of wind and solar.

Interesting recent results from W7-X stellarator in Germany, NIF Laser at Livermore, high-field superconductors from MIT/CFS, negative triangularity on DIII-D & TCV, soon: NSTX-U, …

International ITER experiment (US is a partner) to demonstrate high fusion gain, starts operation this decade. Private industry also proposing next-step experiments.

National Academies panel endorsed goal of constructing a fusion pilot plant by 2035-2040.

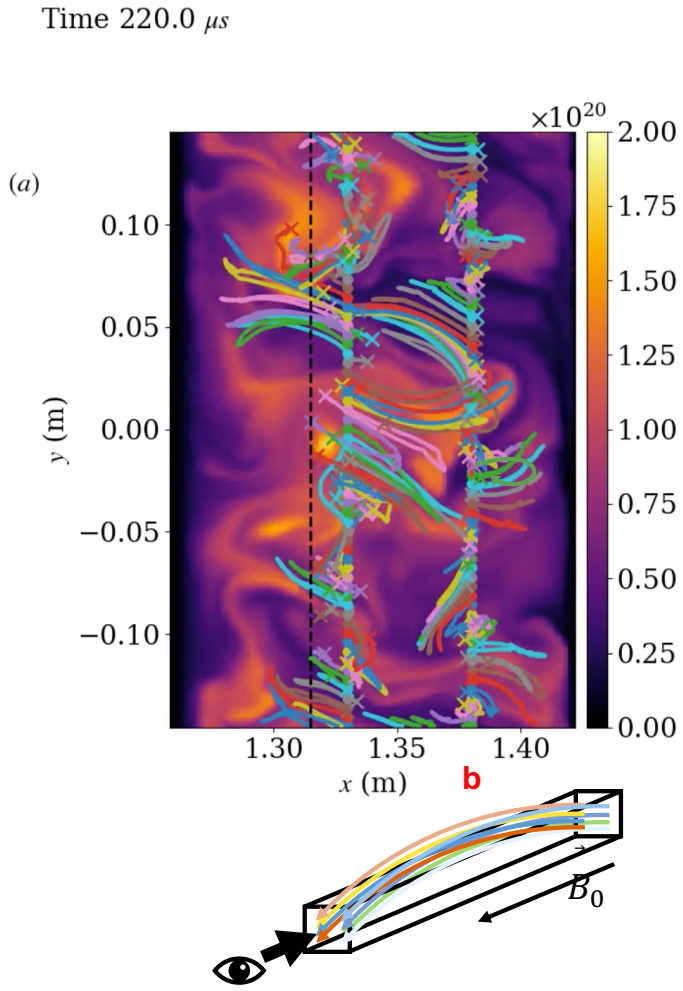
Developing increasingly realistic computer simulations to help design better fusion reactors

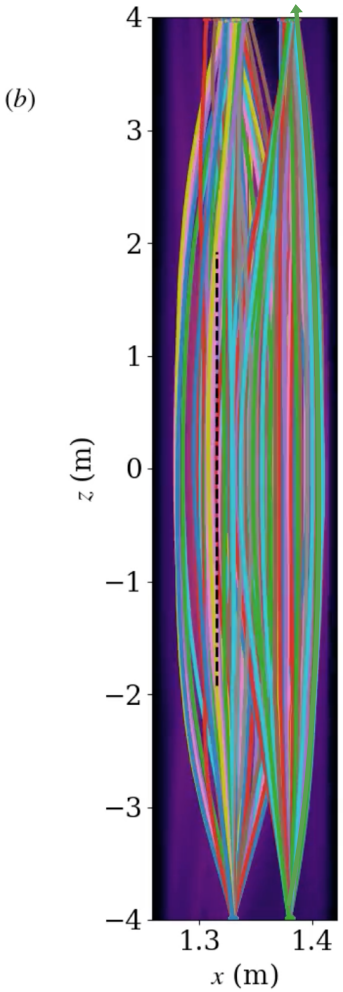


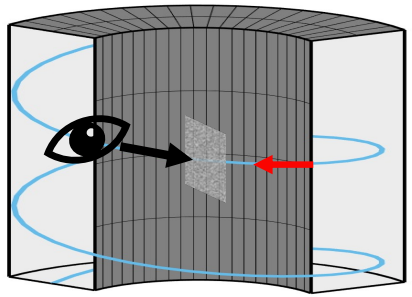
(Waltz, Austin, Burrell, Candy 2006, General Atomics)

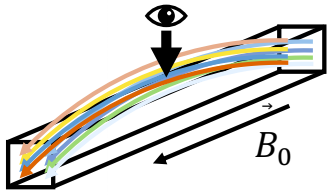
- 1990's-2000's: demonstrated fairly sophisticated plasma turbulence codes could explain key features of experiments in core region of tokamaks.
- Supercomputers: 1 million x faster than 25 years ago.
- Tokamaks are very complicated (multi-scale dynamics of many physical phenomena) and so are the codes we need to simulate them, it requires a lot of expert human effort to write these codes with efficient, stable algorithms.
- Present challenge: Edge region of tokamaks (near a physical wall) much harder to simulate.
- Multiple codes making progress (Gkeyll, XGC, …), essential to be able to cross-check on these challenging nonlinear chaotic problems.

Edge plasma turbulence codes recently able to handle magnetic fluctuations (previous numerical stability problems)







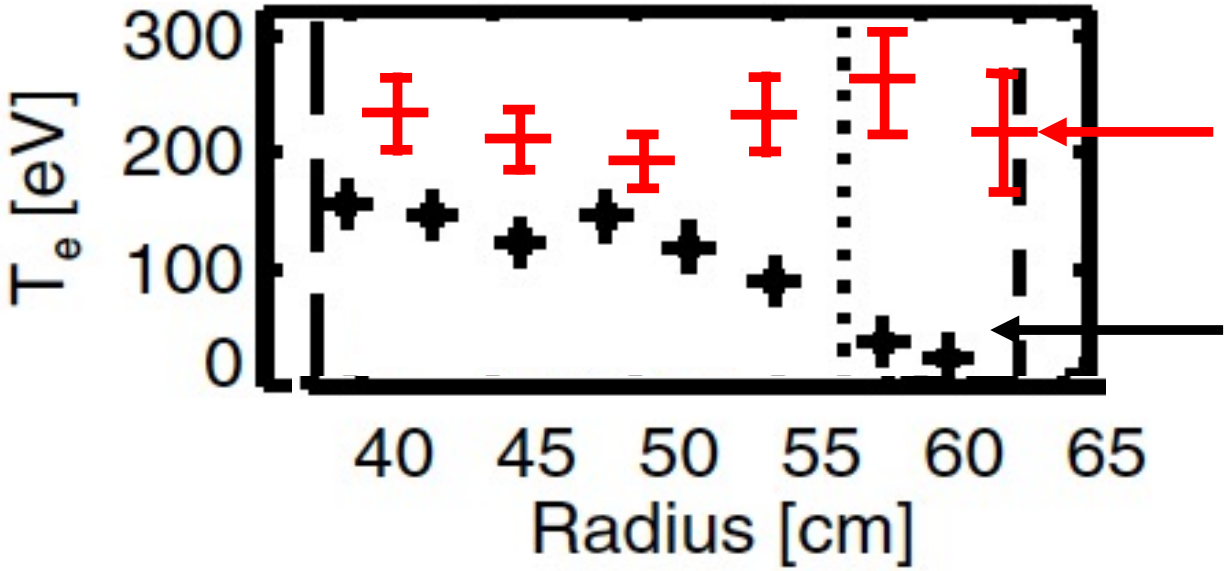


Mandell, Hakim, Hammett, Francisquez, JPP 2020

Plan to apply this code some ideas that may help make fusion cheaper, and how these methods would scale to a power plant:

Lithium Tokamak Experiment (LTX-beta) @ PPPL:

Liquid metal lithium: lithium-coated walls raises plasma temperature, reduces turbulence



Lithium-coated walls enable low-recycling regime

Regular high-recycling regime: cold neutrals cool the edge

(Boyle, Majeski, et al., PRL 2017)

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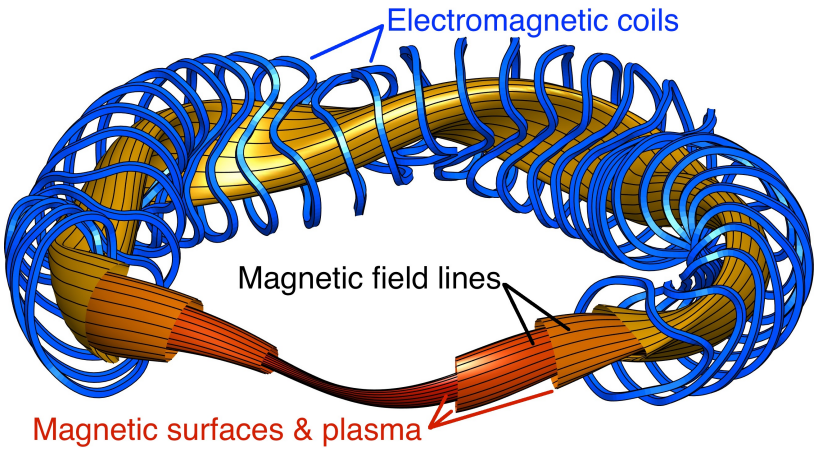
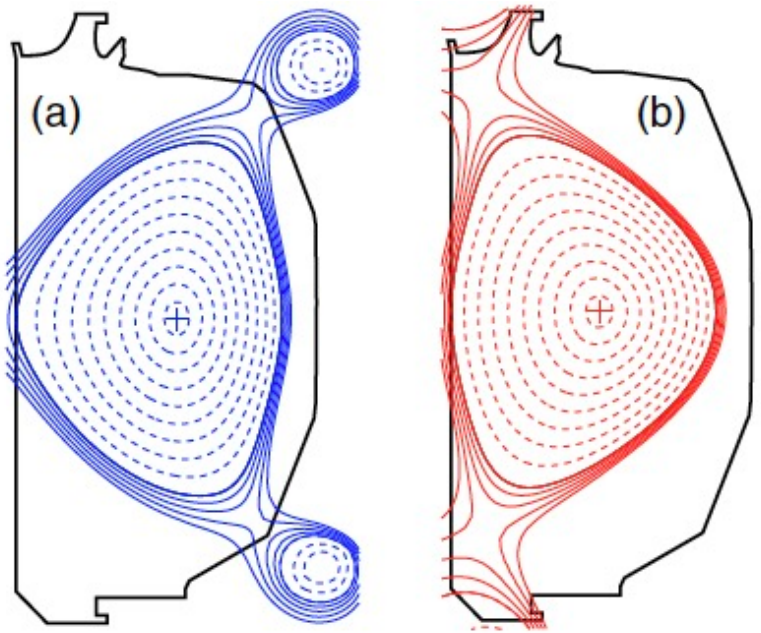
- Innovative shapes for the magnetic cage, can reduce turbulence & increase temperature
  - Negative triangularity tokamaks
  - New stellarator designs



Reverse triangularity tokamak:

Regular D-shaped tokamak:



Austin et al. & D3D team at General Atomics, PRL 2019

W7-X stellarator in Germany, M. Landreman, https://terpconnect.umd.edu/~mattland/projects/1_stellarators/

This is a team effort – thanks to many!

Early Fusion Collaborators: Bill Dorland, Mike Kotschenreuther, Mike Beer, Ron Waltz, Steve Cowley, Andris Dimits, Darin Ernst, Frank Jenko, Jeff Candy, Bill Nevins, …

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Other fusion scientists I haven't directly worked with: but we all benefit from each others progress in journals and interacting at scientific meetings.

- Experimentalists, whose measurements of real plasmas help guide development of theory & computer codes.
- PPPL leadership & staff: engineers, technicians, cafeteria workers, maintenance, business, administrative staff, for keeping the wheels of science turning
- DOE Office of Fusion Energy: shepherding the program with wisdom and foresight
- American Taxpayers
- My parents, family, church family, friends, former teachers, professors, ...
- Particularly thank my wife, Kate, for all her love & helping me stay balanced (at least somewhat).