PPPL PRINCETON PLASMA PHYSICS LABORATORY [1]
HUNTER The City University of New York [2]

Driven Steady States Dynamics in Flowing Plasmas

Elena L. Mitra[1,2]

Advisor: **Prof. Nathaniel Fisch[1]**
with E. J. Kolmes[1], M. E. Mlodik[1], I. E. Ochs[1], T. Rubin[1]

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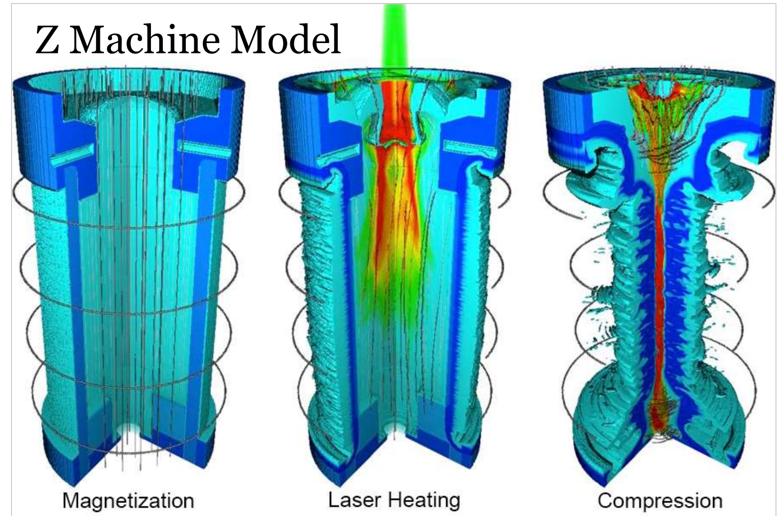
Motivation

- Improve inertial and magnetic fusion efficiency.
- Ion species separation for nuclear waste management.

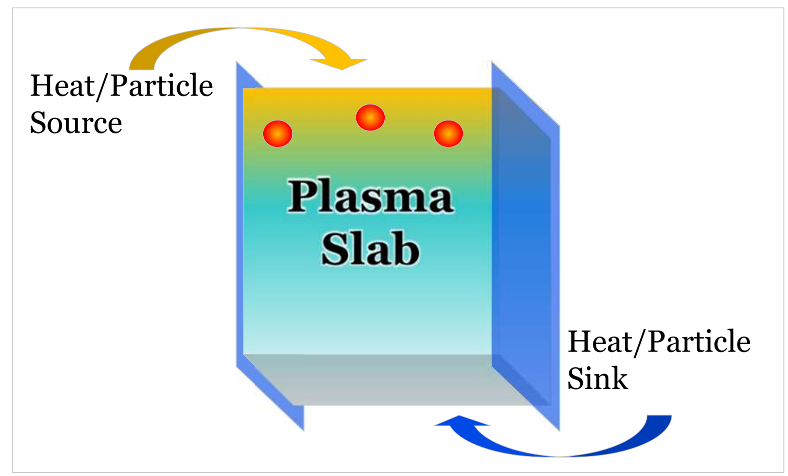
MITNS
(**M**ultiple-**I**on **T**ransport **N**umerical **S**olver)
Elijah Kolmes, Ian Ochs

- 1D code to simulate collisional transport of particles, momentum, and heat in magnetized plasmas.
- Reflecting boundary conditions, no sources or sinks. Thus can only model an isolated system.

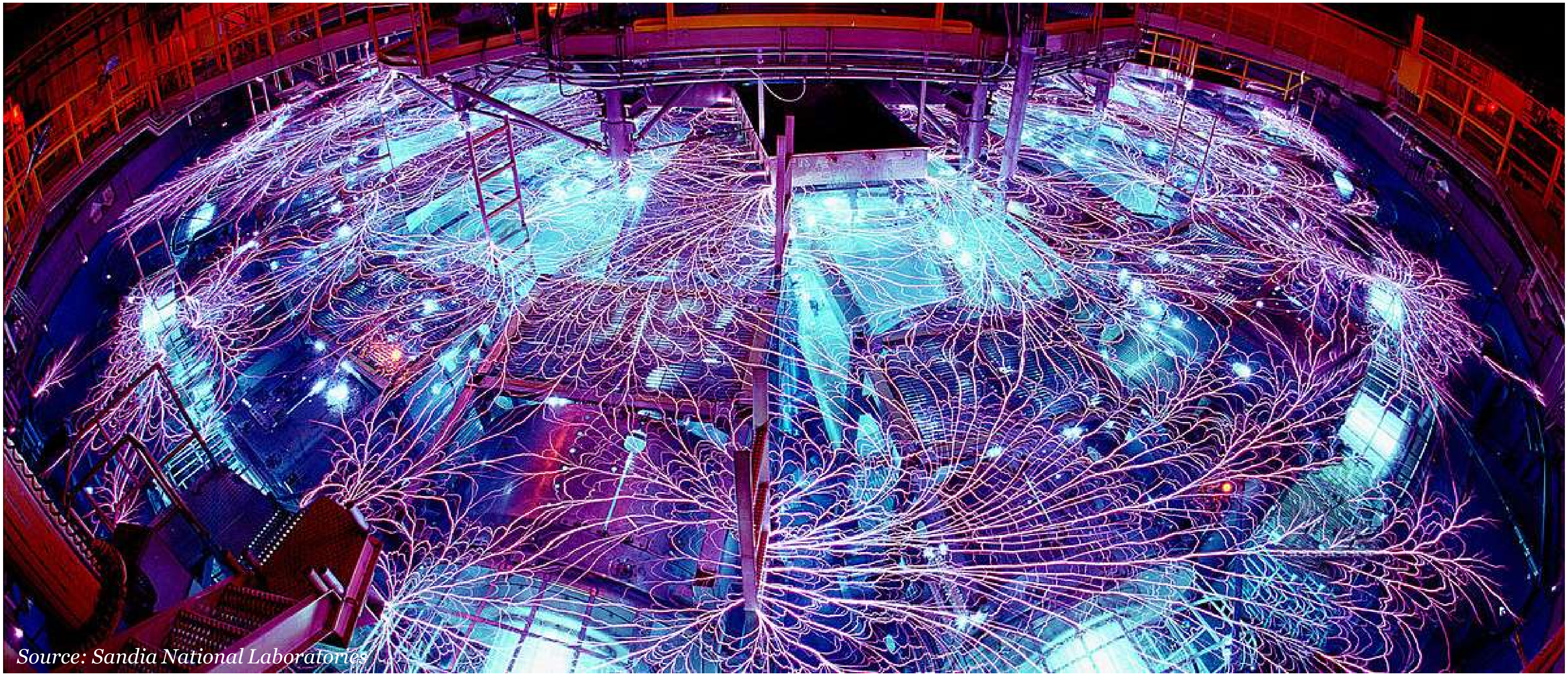
- The addition of sources/sinks is required to examine a driven steady state such as in the Z Machine.



Source: Sandia National Laboratories



Z Machine



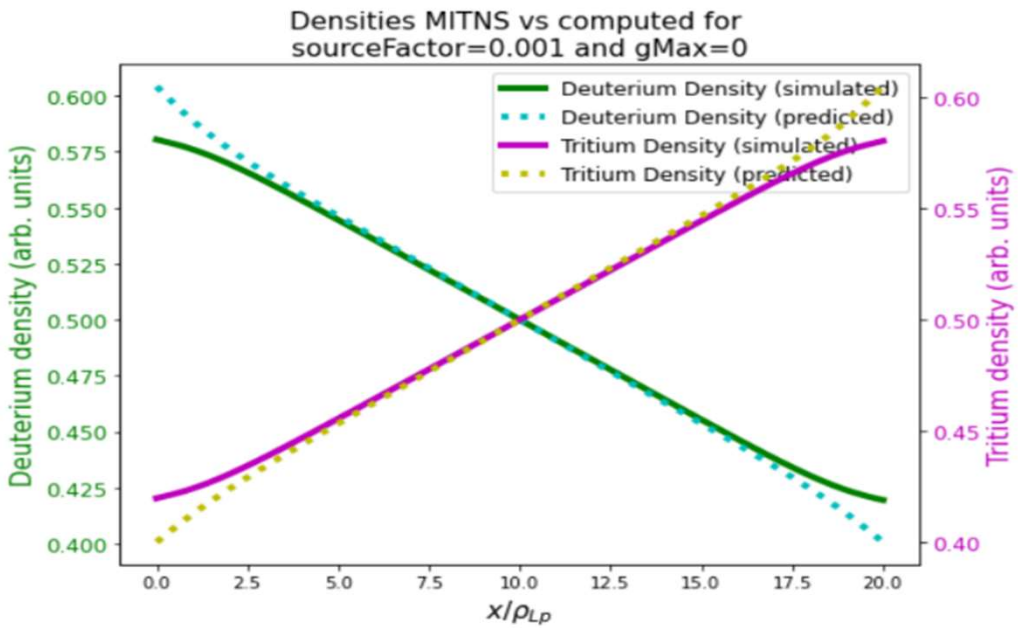
The Z Machine in operation at Sandia National Labs

Method

- Add capability to include sources/sinks in the MITNS code with the simple setup:
  - Temperature is constant
  - Initial velocity of source is zero
  - Particle source rate is constant

- Simulate special case where the two sources/sinks are at the two boundaries opposite each other and ejected on the other side and test at:
  - Potential = 0
  - Potential ≠ 0
  - With trace impurity.

- Verify results analytically.



Results: Trace Impurity

- Our analytical prediction of the trace impurity density profile, assuming linear densities for the source species, is:

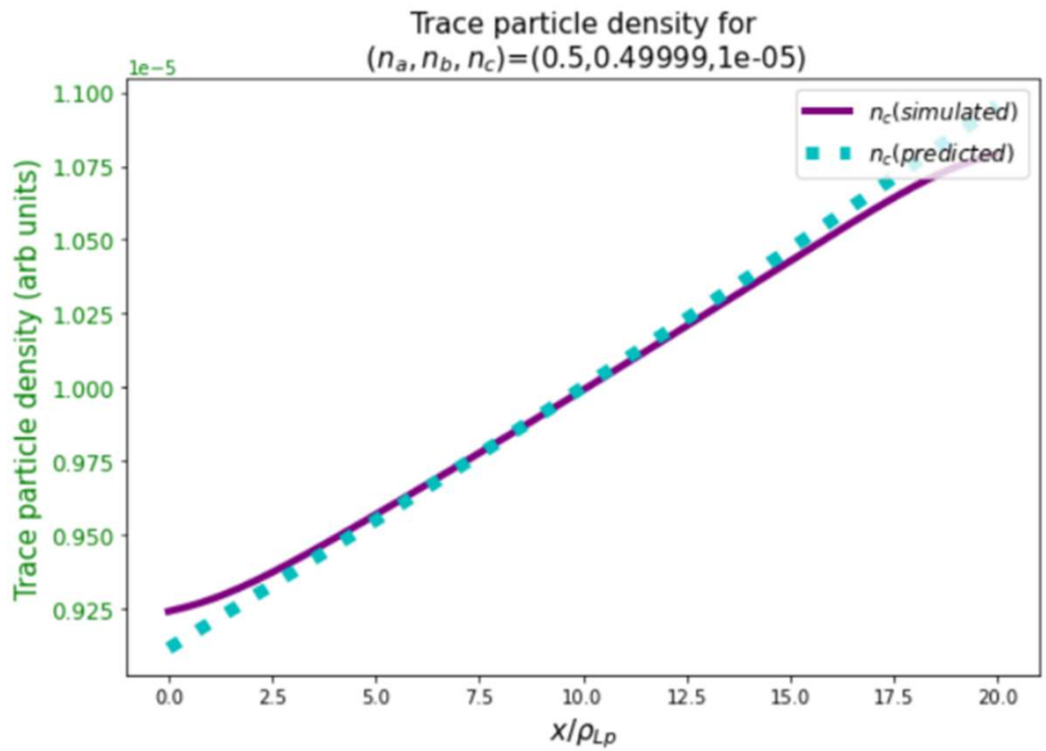
$$\frac{n'_{cm}}{n_{cm}} = \left(\frac{\tilde{B}^2 S n_{am}}{\sqrt{m}_a \tilde{T} C_0 Z_a^2}\right) \frac{Z_{cr} Z_{br}^2 \left(\sqrt{\frac{m_{br}}{m_{br}+m_{cr}}} - \sqrt{\frac{1}{1+m_{cr}}}\right)}{\left(n_{am}\sqrt{\frac{1}{1+m_{cr}}} + (1-n_{am})\, Z_{br}^2 \sqrt{\frac{m_{br}}{m_{br}+m_{cr}}}\right)\left(n_{am} + (1-n_{am})\, Z_{br}^2\right)\sqrt{\frac{m_{br}}{1+m_{br}}}}$$

- *With free parameters:*

Parameter	Definition
S	Source Factor
Z_{br}, Z_{cr}	Ratios of Charges
m_{br}, m_{cr}	Ratios of Masses
n_{am}	Relative Density

- For this special case we find that **the trace impurity tends to align with the higher mass source species**.

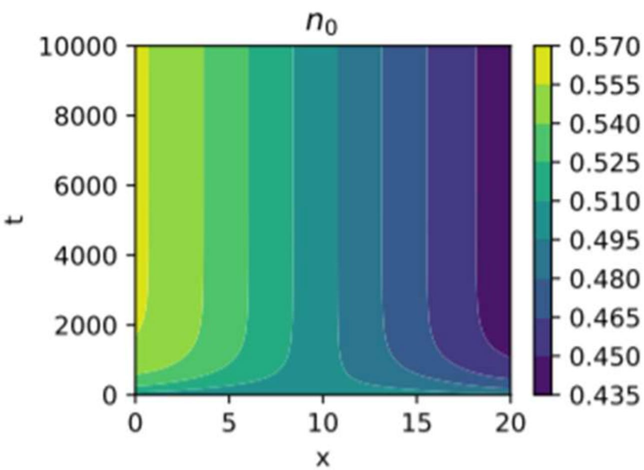
Results: Verification



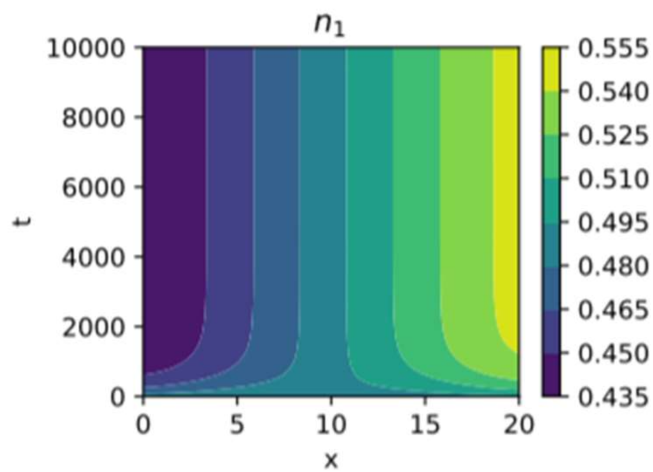
- Density of the trace species computed from the analytical result vs the simulated result.
- As you can see our analytical prediction matches up will with the MITNS code output.

Results: Trace Carbon Impurity in DT Fusion

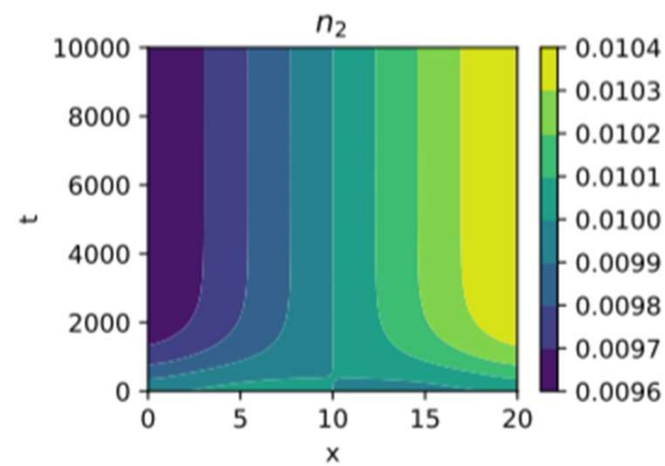
Source ***a*** = Deuterium (^{2}H)
Relative density = 50%



Source ***b*** = Tritium (^{3}H)
Relative density = 49%



Trace Particle ***c*** = Carbon (^{12}C)
Relative density = 1%



Carbon impurity lumps with the heavier source, ***Tritium***

Summary

- MITNS is a novel way to investigate collisional transport of particles, momentum, and heat in magnetized plasmas with a simple model.
- Adding source terms reveals curious dynamics of trace impurities.
- In the special case of two sources at constant relative densities we predict the trace impurity will shift to align with the higher density region of the heavier source species.
- This result is important for various applications such as
  - In fusion where the trace comes in off the walls or another source.
  - In nuclear waste management where we can use this result to separate out harmful particles.

Future Work

- Further analyze these results to predict families of solutions.
- Add a potential field.
- Propose experiments.
- Understand the physics behind our result.

Thank you

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