DTU

Multispecies and impurities

Motivation

- Multicomponent plasmas are a necessity
- Impurities are unavoidable

> As the world's tokamak fusion program approaches the transition between research experiments and the first generation of burn experiments, it is appropriate to assess the remaining major plasma physics issues. Prominent among these is impurity transport and control. Recently, reactor

Figure: S.P. Hirshman and D.J. Sigmar 1981 Nucl. Fusion 21 1079

Impurities and non-main ions

How should the impurities be treated?

- Passive
  - Trace particles
  - Non-interacting fluid
- Interactive
  - Kinetic (TSVV 6)
  - Fluid (our choice)
    - MIHESEL: 2D Drift fluid model implemented with Feltor dg library.

Multispecies model: Equal footing

Treat all ion species equally, even impurities.

- All ions follow same set of equations.
- Challenge is in the closure of the equations and getting
  - Resistive force
  - Viscosity
  - Heat flux
- We use the Zhdanov 21-moment closure
  - Reduces to Braginskiis closure in single species.
  - Contains plasmadynamical, 'priviliged' and 'non-privilged' moment
  - Addition of 'non-priviliged' adds to accuracy
  - Accurate for $T_\alpha \simeq T_\beta \simeq T_i$
    - Need improved closure?

How important is new closure?

An assumption in the Zhdanov 21-moment closure is $T_\alpha \approx T_\beta$

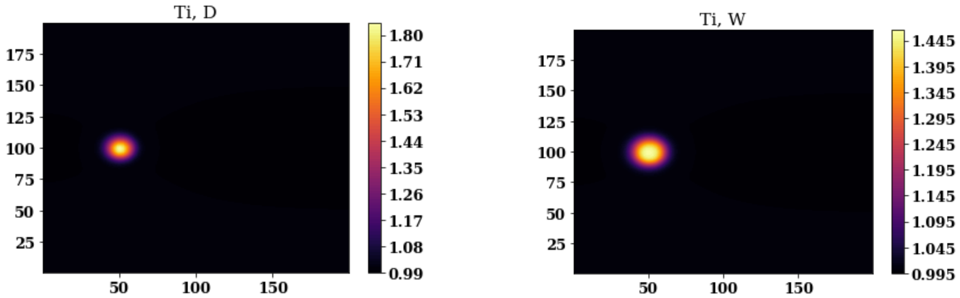
- But is it really necessary?

For sake of argument allow ion temperature to develop independently

- Blob simulation with tungsten
- Perturbation in both density and temperature.

Temperature perturbation in blobs

Temperature in normalised units (40eV) at $t = 100\Omega_D$. Same initial temperature distribution.



Temperature perturbation in blobs - continued

Peak temperature affected by mass and charge

	T_D	T_W
Z=1	1.8	1.7597
Z=2	1.8	1.5517
Z=3	1.8	1.4937
Z=4	1.8	1.462

So; improved closure will be very beneficial.
Fortunately recent papers are closing the gap [1].

[1] Raghunathan M et al. Multi-temperature Generalized Zhdanov Closure for Scrape-Off Layer/Edge Applications
Raghunathan M et al. The 21N-moment multi-temperature coefficients for Zhdanov closure

Neutrals, sources and sinks

Ions can exist in different charge states:

- Do we need the partition function?
  - Avoid pre-defined impurity charge population
- How about neutrals and charged particles with charge exchange, ionisation and recombination?
- Sources and sinks already included in the MIHESEL model.
  - Need to implement rates.
- Collaboration with Alexander Thrysøe (not in TSVV3).
  - nHESEL and MIHESEL to be combined into nMIHESEL

Limitations and/or challenges: Drift fluid

- Drift fluid
  - Long time scales and large gradients compared to gyro motion
    - Can be troublesome for low ionized heavy impurities
    - High mass low ionisation state worst!
  - Computational:
    - More species leads to increase in computational load.
    - Complicated potential calculation
    - Large difference in species seems to affect as well (model/implementation specific)

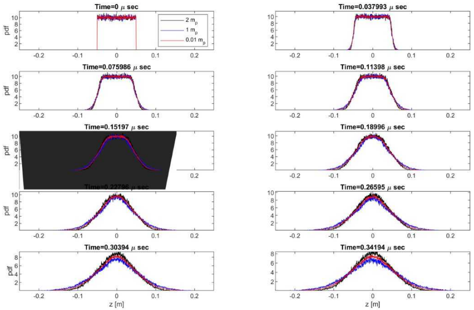
Parallel/3D behaviour

The MIHESEL is 2D but parallel losses are parametrised.
Models small box at outboard midplane.

- How to treat the losses?
  - Blobs expand parallel with sound speed (depletion)
  - Sheath damping on potential also dependent on sound speed.
  - Common sound speed or individual?
  - Currently use common sound speed.

Common or individual

A novel approach: Expansion of two ion species (Courtesy of Anders):



Simple calculation indicates individual sound speed.

Future and summary

- Current MIHESEL model appears insuficient for impurities
    - Implementation of new closure in progress
- Implementing proper source and sink terms with neutrals
    - In conjuction with above: ’new’ nMIHESEL model
- Parallel dynamics: Maybe 3D in the future?