MODELING OF NON-LOCAL PARALLEL ELECTRON HEAT TRANSPORT IN DIVERTOR PLASMAS FROM 1-D to 2-D

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1-D PROBLEM & PROPOSED SOLUTION:

(reminder of Monday's talk)

Present fluid modeling (e.g. UEDGE, B2) assumes :

a) Maxwell-Boltzmann distributions

b) Classical (Spitzer-Härm) heat flow along field lines

This is dubious in steep temperature gradients.

ad hoc "flux limits" are used, but can be insufficient.

Very steep T_e gradients exist near the neutralizer plate.

Non-Maxwellian electron velocity distributions affect:

Heat flow ; ionization and excitation rates etc.

Solution:

Use 1-D kinetic modeling in some *representative cases* to *develop* and *validate* convolution formulas for use in fluid codes.

GOING FROM 1-D TO 2-D

A) Implementing cross-field diffusion and drifts, and 2-D FPI

Ultimate aim:
B2/UEDGE in 2D with non-local corrections for $q_{//}$, *etc.*

How to validate these with the kinetic code?

Cross field transport strongly inhibited by $\vec{B}$; $\chi_\perp << \chi_{//}$.

Velocity anisotropy due to cross field transport negligible.
$\Rightarrow$ Azimutal symmetry in $\vec{V}$ is a good approximation.

Need: Velocity dependent $\chi_\perp(V,\mu,B)$, $D_\perp(V,\mu,B)$, drifts.
For Maxwellian F_0, these should match B2/UEDGE.

$D_\perp,\chi_\perp$ can be regarded as extra source/sink in parallel transport.
"Weak coupling" between "NR" 1-D parallel transport runs.

Development should be analogous to that in 1-D:

1) Perturbation cross field diffusion and drifts in FPI, to obtain NL (non-local) formulas.
2) Implementation into B2/UEDGE.
3) Run 2-D problem, with both FPI and B2/UEDGE. Optimize NL formulas.

B) Variations on cross-field transport

Varying $\chi_\perp(V,\mu,B)$, $D_\perp(V,\mu,B)$,
Exploring the consequences,
And comparing to experiments $\Rightarrow$ important physics.
(Bohm? Neo-classical? Etc.)

Source : cross field diffusion from core plasma.
At first: Assume a (hot) Maxwellian source
Later: Assume non-Maxwellian source
(hotter tail non-thermal,due to current drive etc.),
study consequences.

Variation on parallel transport

Influence of the mirror ratio (NSTX specific)

In NSTX: 2:1 mirror ratio between the separatrix and the plate.

In Tokamaks, this is negligible (≈ 1.1:1).

Heat flow in converging B field : "*Terra incognita*"
(Past work on Mirror machines not applicable:
assumed bounce average $F(\vec{V})$; hotter, tenuous plasmas ;
here, bulk electrons are collisional)

The relevant term could be readily added to "FPI".

What to expect?
Previous runs, for laser heated plasmas showed:
for heat transporting (high V) electrons:

In hotter plasma, $\left\langle V_{\perp}^{2} \right\rangle > \left\langle V_{//}^{2} \right\rangle$

In cooler plasma, $\left\langle V_{\perp}^{2} \right\rangle < \left\langle V_{//}^{2} \right\rangle$ (PRL 1992)

So, a converging B field should enhance this anisotropy:
High μ electrons will be more confined in the hot plasma.
Low μ electrons will stream unimpeded into the mirror.

Changes for heat transport could be included in fluid codes.

Possible experimental verification

A brief list of possible diagnostics for this transport physics

Good spatial resolution would be required

For $F_0(x,V)$ (energy distribution):

Thompson scattering
Line and continuum spectra *
Langmuir probes*

For $F(x,V,\mu)$:

Thompson scattering: Vary measurement angle.
Line and continuum spectra:
Measure angular dependence and/or polarization*.
Directional Langmuir probes. *

For velocity space instabilities:

Measure above-thermal fluctuation levels

* These have been previously simulated with "FPI".

SUMMARY AND CONCLUSION

- Parallel transport in steep gradients is an important issue
- Steep gradients expected in detached plasmas
- Classical conductivity models are dubious in such cases
- Routine use of kinetic simulations prohibitive
- Non-local (NL) transport formulas can be effective in fluid codes
- NL formulas need to be validated by kinetic simulations
- It would be cost effective to use the existing kinetic code, “FPI”, for this development and validation.