TTF 2007

Momentum Transport Working Grp.

P. H. Diamond

Ackn.: J. E. Rice, T. S. Hahm, C. S. Chang

- → 1 preview
- → 12 orals
- → 6 posters

≧ 2 1-Day Meetings { S.D. 2/07 ; N.Y. 3/07

Others Welcome!

Common Themes - mostly ρ_{11}, ρ_ϕ

→ <u>basic physics</u>

- structure of $\Pi_{n,11}$
- cross phase
- b.c.'s → physics and role (edge)

① structure of momentum flux $\Pi_{n,11}$?

- nature of $\begin{cases} \text{off-diagonals} \\ \text{non-diffusive} \end{cases}$?
  $\nabla \langle v \rangle$, S
- perturbative tests ?

Solomon, Bertolon, Duncan, Hahm, Waltz

② physics of cross phase ?
(Basic experiments important!)

- $\langle v_E \rangle'$? other ?
- fluctuation signatures

Hidalgo, Z. Yan, P.D.

③ Boundary Conditions - physics and role

- structure / classification
  Ince-Cushman, Rice
- dynamics - macro + micro
  Bonfalon, Naulin

→ Special Topics :

⇒ (multiple) origins of intrinsic rotation

- types of 'spin-up' transitions
  core vs edge ?
  and
  transport bifurcation vs spin-up ?
  Rice ($\langle v_E \rangle'$) (mode prop.)
  Bonfalon, P.D.
- fluctuation signatures McKee
- R.F. interaction → control!?
  Van Dam, Kin. Wong
- scalings - ρ_* !
  Waltz

⇒ Theory, Simulation and Modelling of Momentum Transport

- theoretical novelties

$V = V_{TE\rho} + V_{T.E}$ (Hahm)

Wave } momentum (P.D.)
R.P. }

- coordinated simulation, data analysis modelling (Waltz, Budny)

⇒ Poloidal Momentum Transport, Zonal Flows

- structure of $\Pi_{r,\theta}$ (Gurcan)
- rational q's and Z.F. (Naulin)
- DWT with $\langle \tilde{v}_r \tilde{Q}_\alpha \rangle$ (Naulin)

⇒ Macro-MHD in RFP (Ding, Kuritsyn, Ebrahimi)

- lessons learned ↔ contrast
- useful interaction with tokamak/ITER community

⇒ 'lab' for multi-scale problems

Some Trends & Highlights

①

→ Need/Physics Basis for Non-Diffusive Momentum Transport by Turbulence

Modelling Needs: macroscopics

$$\pi = -\chi_\phi \frac{\partial \langle v_\phi \rangle}{\partial r} + \underbrace{V \langle v_\phi \rangle}_{\text{pinch}} + \underbrace{S}_{\text{residual stress}}$$

S = piece $\langle \tilde{v}_r \tilde{v}_\phi \rangle$ not proportional to $\langle v \rangle$, $\partial \langle v \rangle / \partial r$ i.e. $\sim \langle p \rangle'$, etc.

- Solomon: T_ϕ vs T scans, DIII-D → off-set?
- Bortolon: Profile evolution at limited, diverted OH spin up? V want work.

Perturbative Tests — dual v, n; v, T
— i.e. beam + ECH, braking etc.

Physics Basis: (builds on much previous work)

- $\langle v_E \rangle'$ → cross phase
  - → Guercan - self-consistent model
  - → Waltz - verified predicted null-point
  - → Hidalgo - biasing scans showed sensitivity to $\langle v_E \rangle'$ of $\langle \tilde{v}_n \tilde{v}_{11} \rangle / (\tilde{v}_n^2 \tilde{v}_{11}^2)^{1/2}$

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②

→ Rich, Complex Variety of Spin-up 'Bifurcations'

before: - Rice scaling - H-mode
L mode ?

after: → L-H transition $-\langle v_E \rangle'$ → {Rice / A.I.C.

→ ∩ ∧ core spin-up in T_e const

TCV limited (Bortolon)

$v_{re} \rightarrow v_{ri}$ with $\langle v_E \rangle'$?

after, cont'd

→ coupled core-edge bifurcations
on TCV diverted (Bortolon)
sometimes opposite behav.....
⇒ independent knobs on core, b.c. !
→ JOG experiments !
→ indications of SOL flows role
on C-Mod L-Mode (Rice, Hubbard)
→ SN vs DN comparisons !

Synthesis :

$$V = V_{exp} + V_{Rice} \quad (A.I.C.)$$

V_{exp} ⇐ L-mode edge physics

alternative :

$$V = V_{exp}^{edge} + V_{exp}^{core} + V_{Rice}$$

V_{exp}^{edge} ⇐ as above
V_{exp}^{core} ⇐ OH scan.

Missing : - ITB impact on Intr. Rot. !
- Obl barrier ?

Other Aspects:

- fluctuation studies (MC here)
  - indication of flow effects on L-H transition
- R.F. effects
  - R.F. QL scatt. with precession drift – possible explanation of Intr. Rot. in ICRH, ECH plasmas (Van Dam)

⇒ OH result ? – "lively reception"

⇒ use as control technique? (K.-L. Wong)

Generic Issue: Rotation Controls ?

→ waves, fast particles, EP modes, magnetics ?

→ thought to EP mode impact on momentum transport ?!

③ Advancing Theory, Simulation, Modelling

- theoretical novelties
  - 'pinch' for $\langle V_{11} \rangle$ (Hahm, et. al.)

$$V = V_{TEP} + V_{ion\ thermoelectric}$$

$V_{TEP} \rightarrow$ nV_{11}/B^2 locally advected.

& pinch: n flat $\frac{\partial_r \langle V_{11} \rangle}{\langle V_{11} \rangle} = 3\frac{\partial B}{B}$ canonical

but: $V_{TE} \rightarrow$ in for V_{te}
out for V_{ti}

$\Rightarrow$ "it depends"

- fluxes. WMD = NRPMO (P. D, et. al.)

formulate - Q.L. for resonant
- wave transport for non-resonant

simple, alternative perspective recovers many/extends previous.

→ simulation and modelling Waltz, Budny

- GYRO addressing S.R. problem
  - → recover null at predicted by theory
  - → indications of ρ* scaling to V (Controversy)
  - → "intense discussion" of
    - b.c.'s for flow
    - importance of fixed-flux b.c., esp. heat

→ other contributors ?
→ fixed flux issue ?

- useful code integration suite developing
  - → GYRO + TRANSP
  - → GYRO + mean field evoln., etc.

④ Relevant Related Topics

→ Poloidal rotation, momentum transport (Gurcan)

- no detailed dynamical theory of turb momentum flux to complement Neo. Theory
- approach via Taylor iden.

$$-\frac{d}{dr}\langle \tilde{v}_r \tilde{v}_\theta \rangle = \langle \tilde{v}_r \sigma^2 \tilde{\phi} \rangle$$

- prelim. results applicable to observed cross phase variation in basic experiment (Z. Yan)
- interplay with $V_\parallel$?

→ Zonal Flows (Diamond)

- elucidates Reynolds vs Maxwell competition
- rational q? → Z.F. displaced (c.f. Max Austin) relative to q res.
- what sets displacement?

⊕ 'MHD' Induced Momentum Transport in RFP (Kuritsyn, Ding, Ebrahimi)

- rare opportunity to confront magnetic stress from turbulence ⊕
- underlying dynamics fundamentally different from μ-turbulence ⊖ (T.M. both)
- good measurements → basic consistency indicated ⊕ ($\pi_\parallel$ on PRL)

Key Issue: Modelling / Interpretation invokes "non-ambipolar transport" ⇒ $\langle j_r B_r \rangle$

Origin?
- → stochastic field? – ⊖ ambipolar
  – momentum?
- → co-existing μ-turbulence { ∇A → resist. coll. ITG

* small scale ∇T correlated with sawtooth crash
  - → ∇P effects on
  - → alteration of T.M. turbulence ⇒ multi-scale interaction in turbulence

Words of Wisdom Relevant!

→ "Truth is never pure and rarely simple!!

– Oscar Wilde

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