Transport and Layering for Marginally Overlapping Cells

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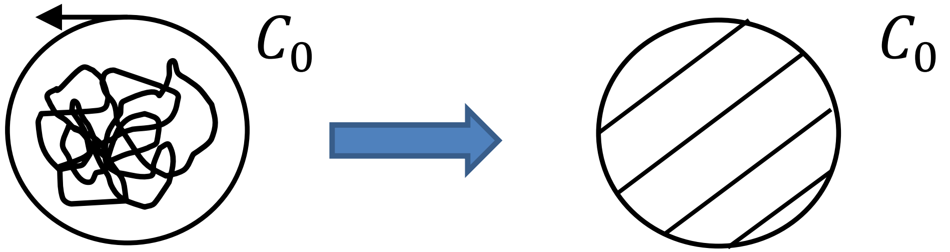
‘What of Layering due Cell Structure and Pattern?’

- B. Shraiman (c.f. Phys. Rev. A, ‘87)

- Single Cell → PV Homogenization



$\tau \sim \tau_c \, Re^{1/3} \;\rightarrow\; \tau_c Re$

C_0 – boundary streamline

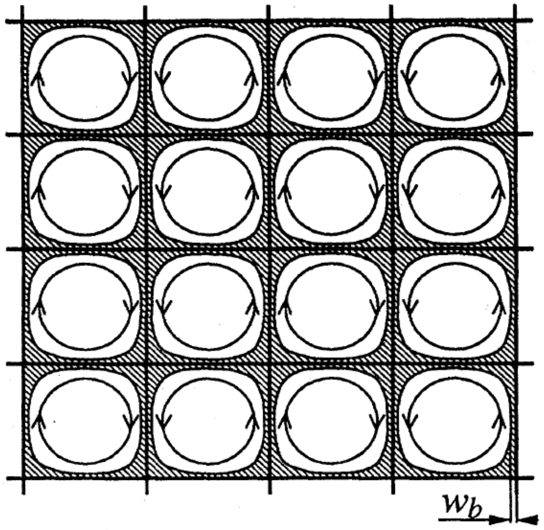
- Boundary → $\nabla(PV)$ large

  → Strong ‘Rossby Wave Elasticity’ $\quad \omega \approx \frac{k_x \nabla q}{k^2}$

  → Barrier !?

- Homogenization ↔ Barrier Connection

Cell Pattern? – It's about layering!

- 

Isichenko Review

~ overlapping cells

- Cell pattern
- Cells $V_0,\ l_0$
- Molecular diffusion D_0

➔ What is $\langle D \rangle$?

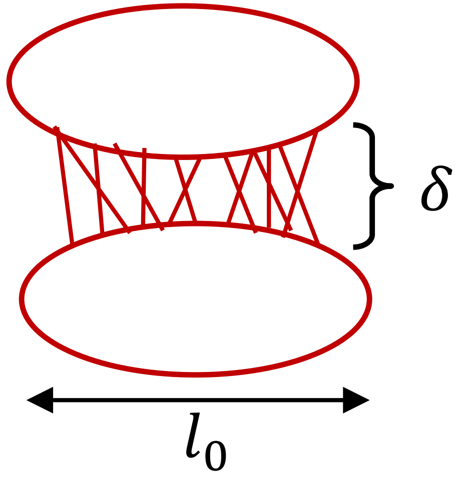
- See Rosenbluth, et. al. Phys. Fluids (1987) for detailed analysis
- Physics:
  - Irreversibility localized to boundary layers between cells
  - Global transport hybrid of { Fast kicks thru cell / Slow diffusion thru BL } ➔ ?

Back-of-Envelope Calculation

- $D_{eff} \approx f_{active} \, ((\Delta x)^2 / \Delta t)$

  f_{active} → active fraction

  $$f_{active} \sim \delta / l_0$$



$\delta \rightarrow$ BL width
$l_0 \rightarrow$ cell size

- And: $\Delta t \sim l_0 \,/\, V_0$ → cell circulation time

  So $\delta^2 \sim D_0 \Delta t \sim D_0 \, l_0 \,/\, V_0$

$D_0 \equiv$ molecular diffusivity

- $$D_{eff} \sim \left[\left(\frac{D_0 l_0}{V_0} \right)^{1/2} \frac{1}{l_0} \right] \left(\frac{l_0^2}{l_0} V_0 \right) \sim [D_0 D_{cell}]^{1/2} \sim D_0 (Pe)^{1/2}$$

  (Pe) → enhanced diffusion

➔ not simple addition …

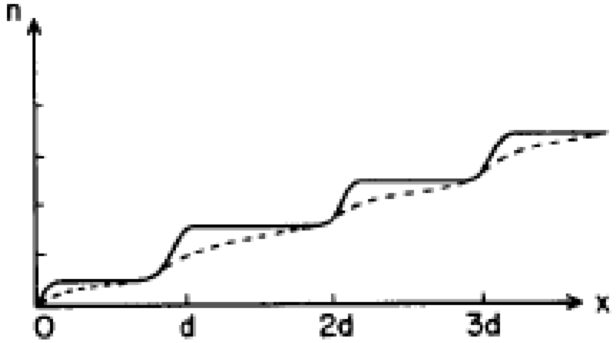
Profile ?

- $D_{eff} \sim D_0\,[Pe]^{1/2}$ but actually { Slow transport thru layers / Fast mixing in cells }
  ↓
  averaged

- Consider concentration of injected dye → profile

from:

Rosenbluth et. al. '87



→ Layering !

➔ "Rosenbluth Staircase"

"Steep transitions in the density exist between each cell."

- Conclusions supported by detailed analysis c.f. { Rosenbluth, et. al. '87 / Shraiman, '87 }

Discussion

- Seems quite relevant to the eternal discussion of “near marginal stability”
- D_0 → interpret as { neoclassical
ambient small scales
- “But this is contrived. Its not self-organized !”

  → Not so clear…

  – ‘pinned cells’ at $\vec{k} \cdot \vec{B}_0 = 0$ surfaces

  – $\Delta r \,/\, L_\perp \ll 1$ → small ρ_*

  – ~ near marginality ↔ barely overlapping cells, islands

➔ a “naturally” self-organized state, supporting staircase !

➔ consequence of drive + profile stiffness

➔ irregular staircases likely. Low q ↔ large step !?