Mini-stories from Engineering Puzzles of a Fluid Dynamicist

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ICME XPO Research Symposium
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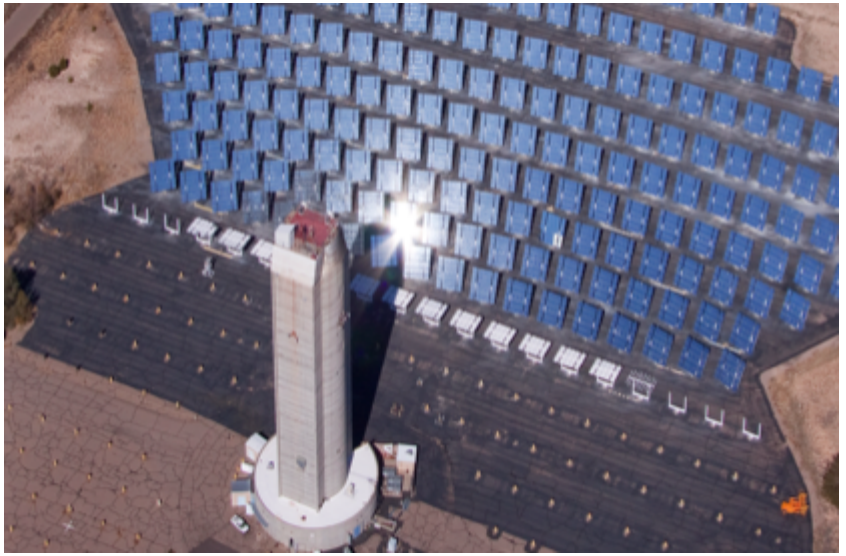
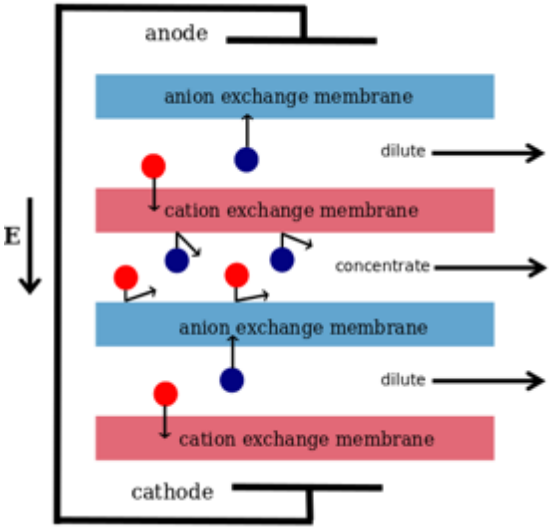
Outline

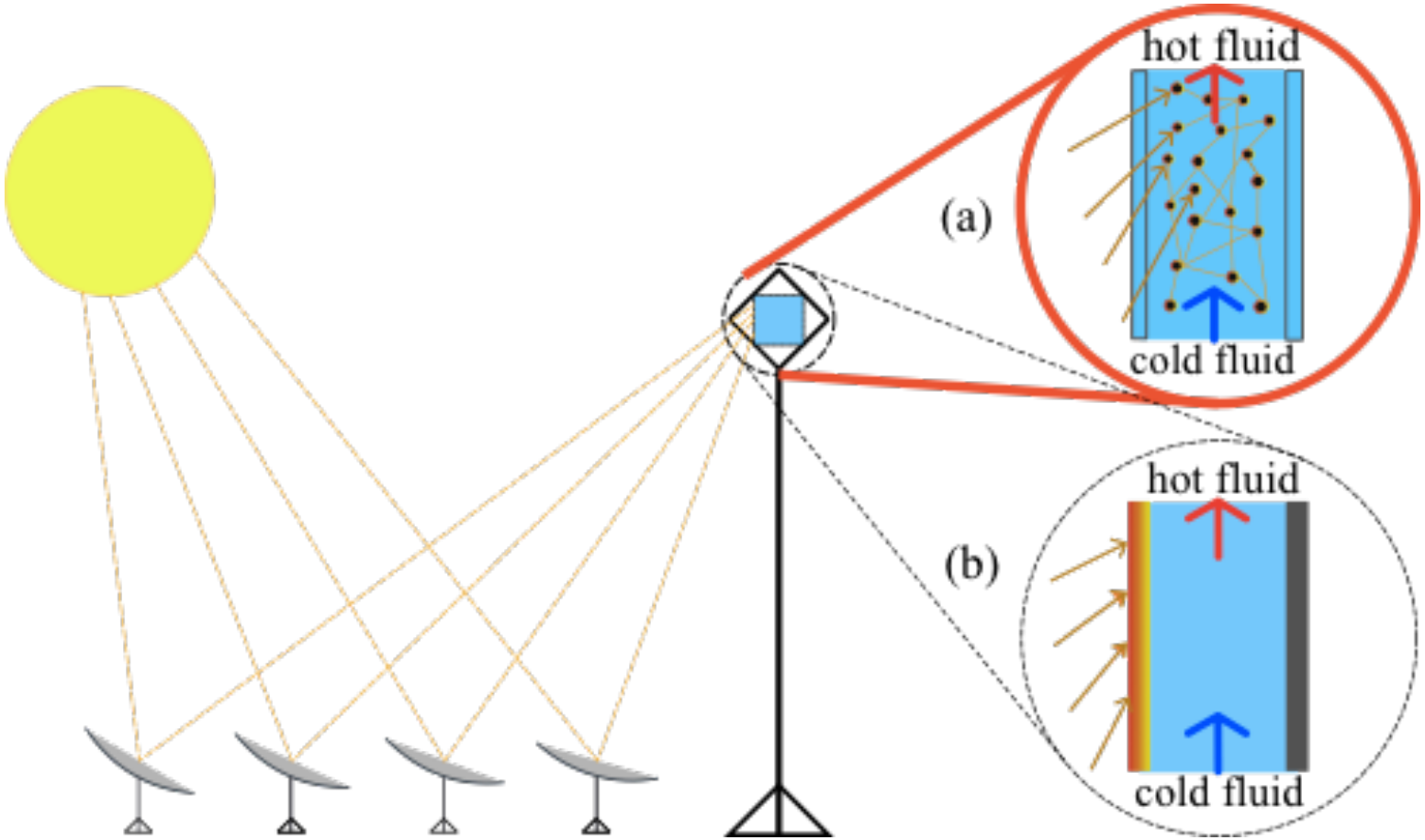
- How to use particles in a gas for solar energy harvesting?



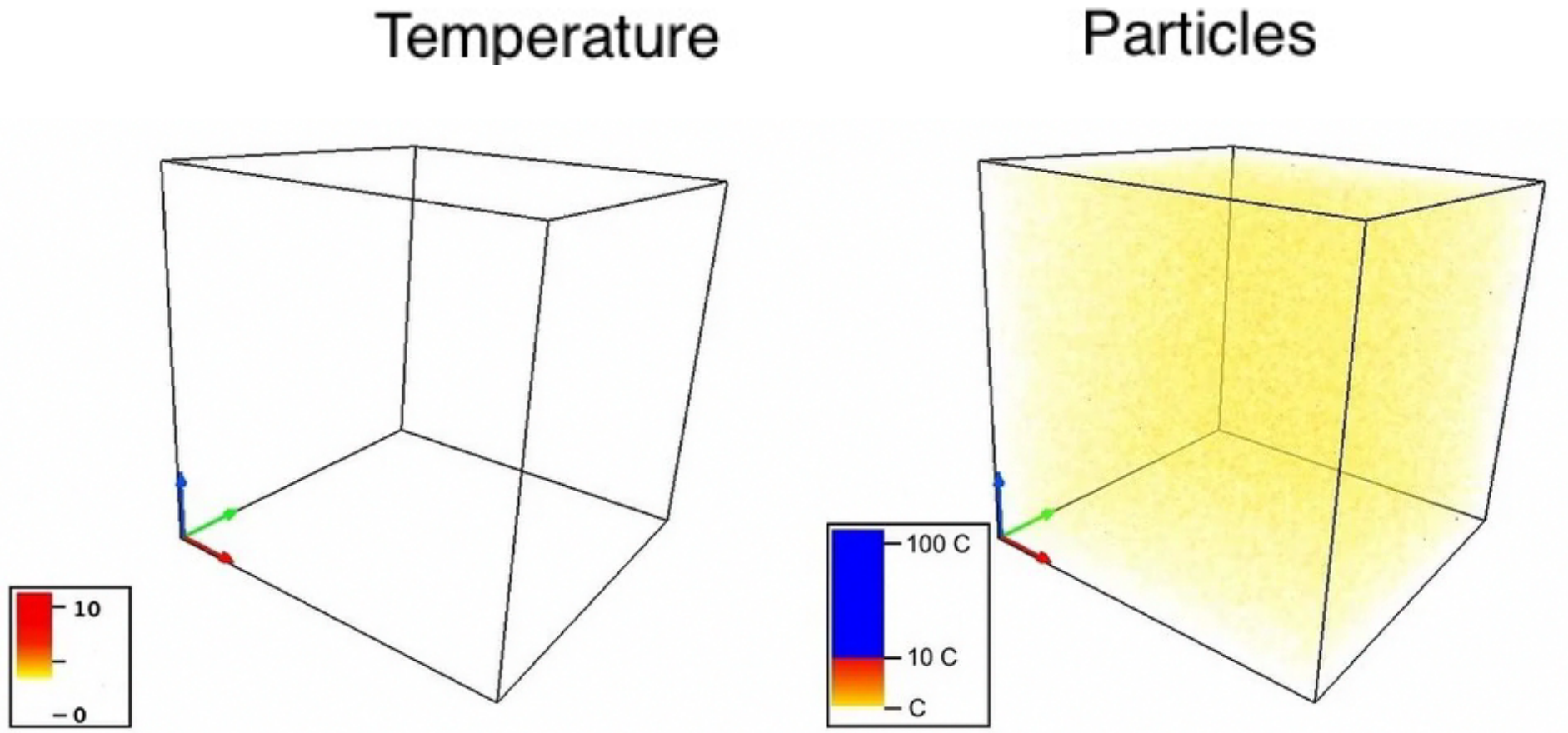
- Complex flows in electrochemical systems



Particle-based Solar Receivers

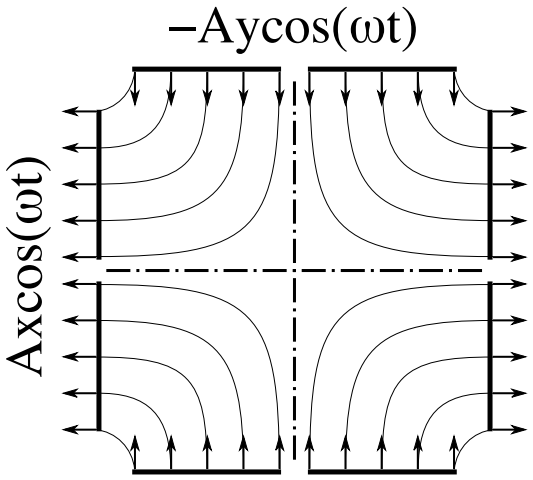


Particle-Laden Flows Subject to Radiation

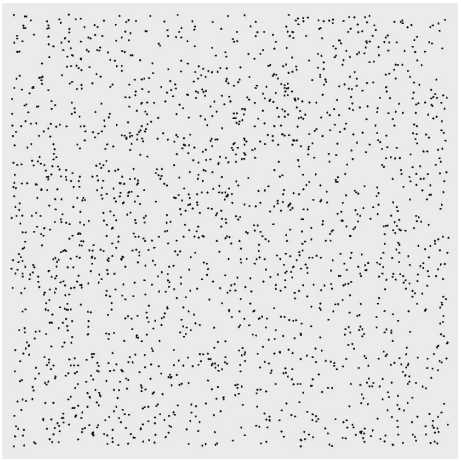


Remy Zamanski, POF 2014

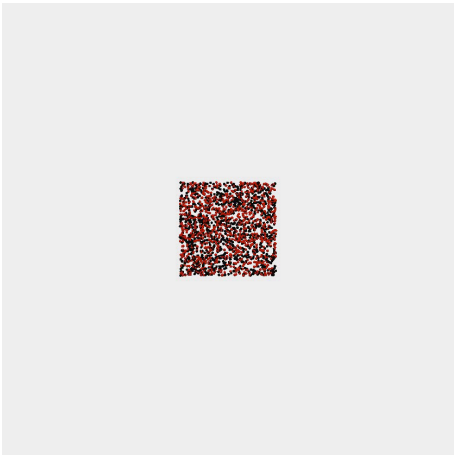
Simple Analysis of Particle Clustering



representative
flow field



particles
in the flow



two sets of particles

Outline

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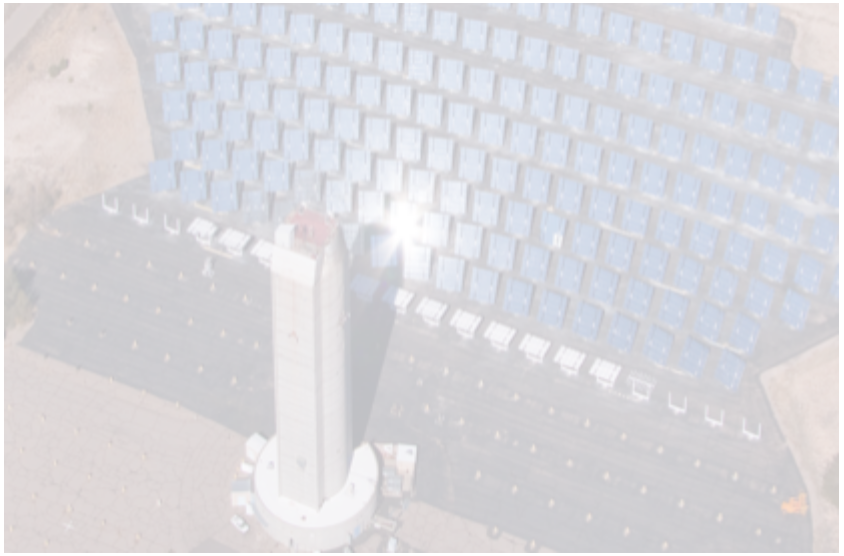
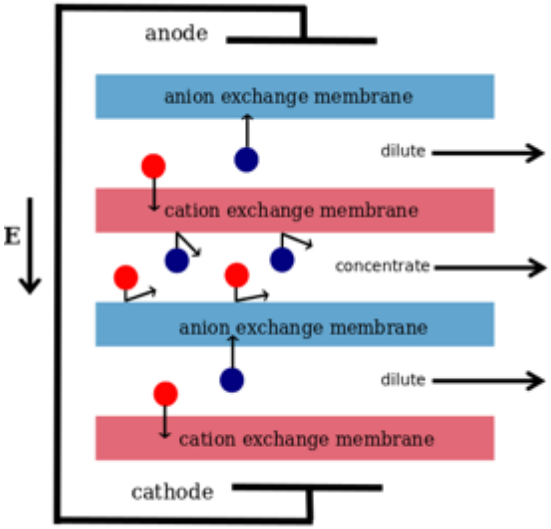
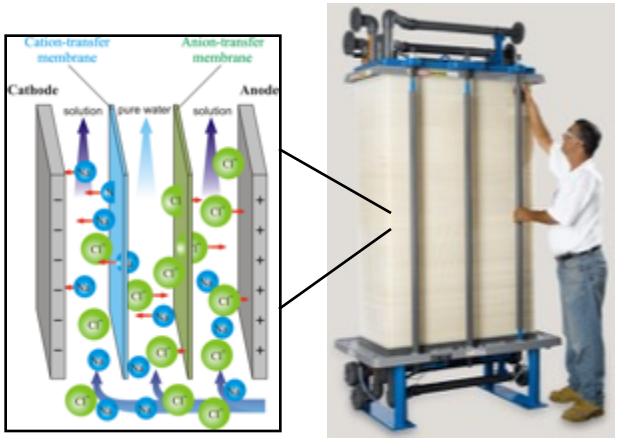


- **Complex flows in electrochemical systems**

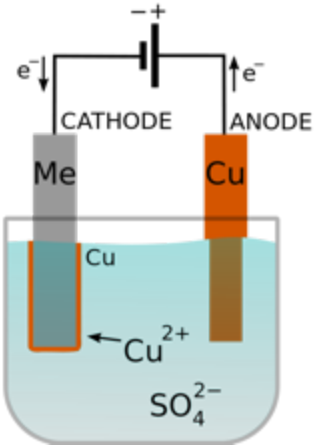


Ion Transport and Electrochemical Interfaces

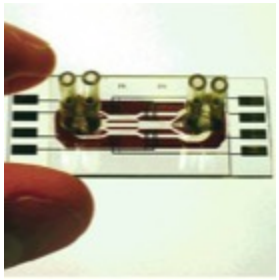


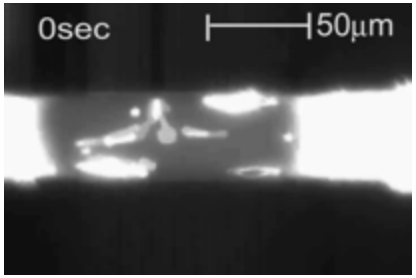
large-scale electrodialysis cells for water purification

left: E. Generalic, right: General Electric



electrochemical systems

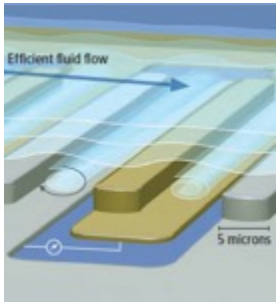




microfluidic labs-on-a-chip for biochemical analysis

left: P.H. Bessetet et al, *Anal. Chem* 2007

right: S. J Kim et al., *PRL*, 2007

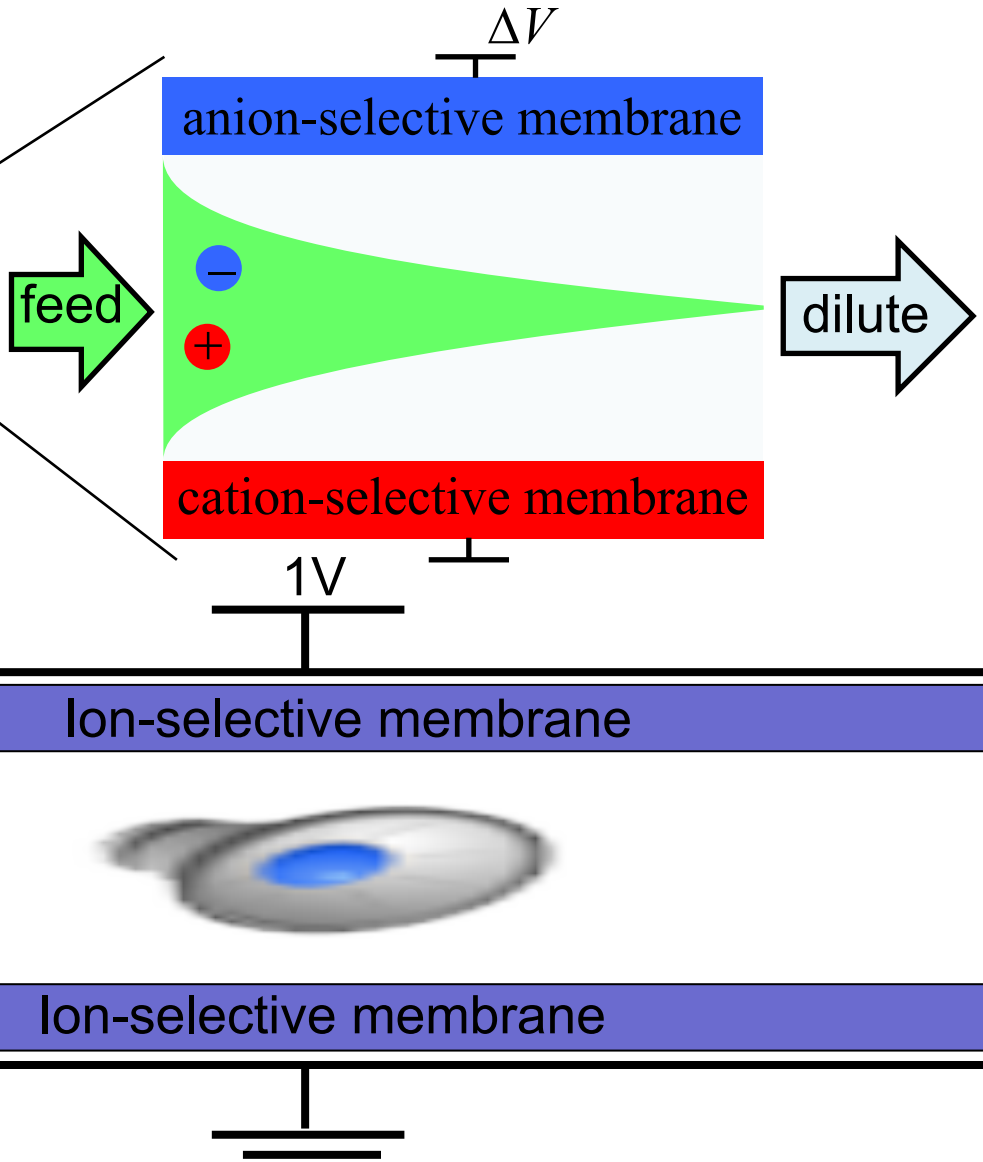


AC electroosmotic micropumps

C.Q. Choi, *Sci. Am., 2007*

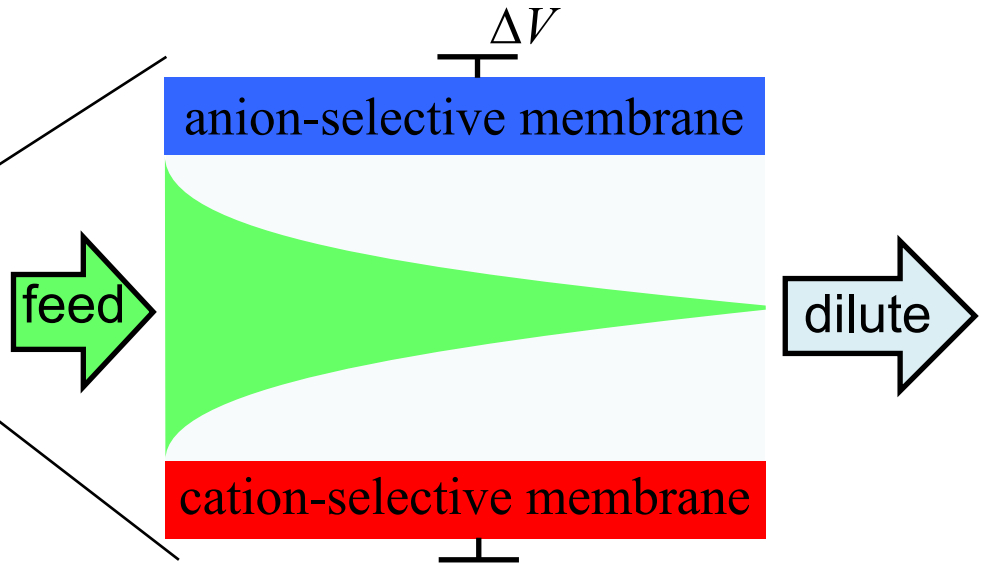
Example Application: Electrodialysis for Desalination

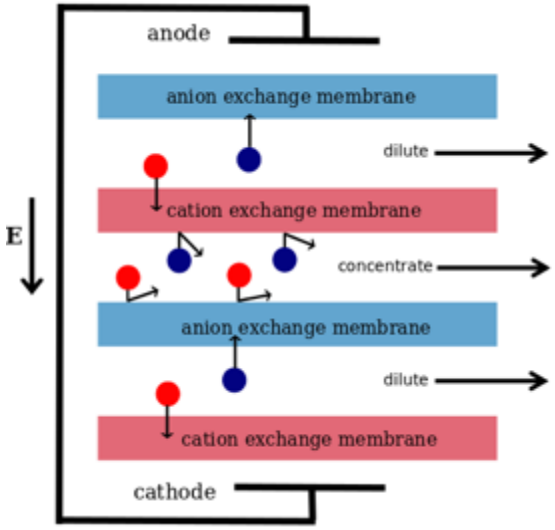
General Electric



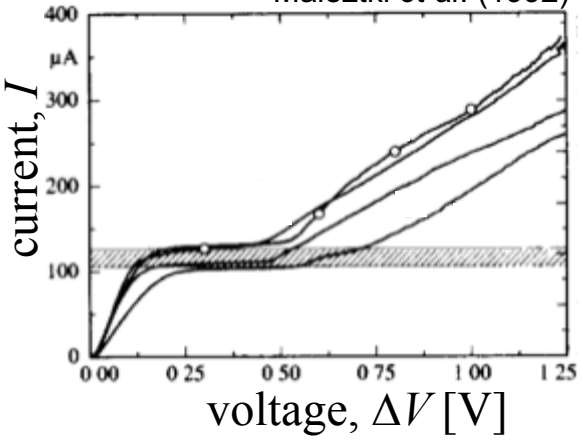
Example Application: Electrodialysis for Desalination

General Electric

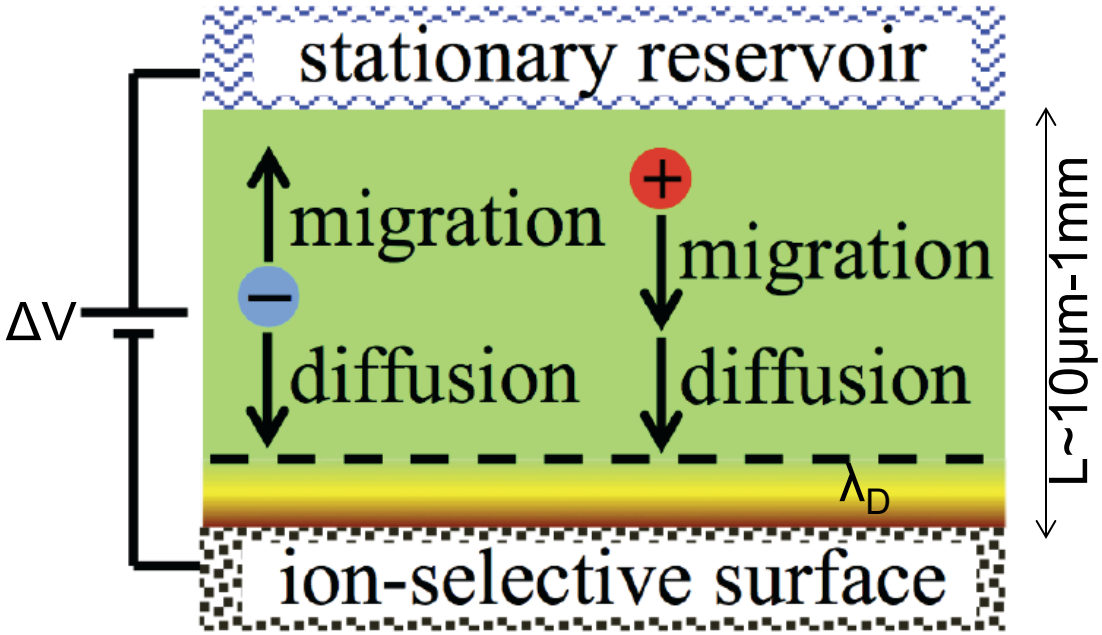




Maleztki *et al*. (1992)



Model System



- **Governing equations**

$$\frac{\partial c_i}{\partial t} + \nabla.\left((\vec{u} + \mu_i \vec{E})c_i\right) = D\nabla^2 c_i$$

Transport equation

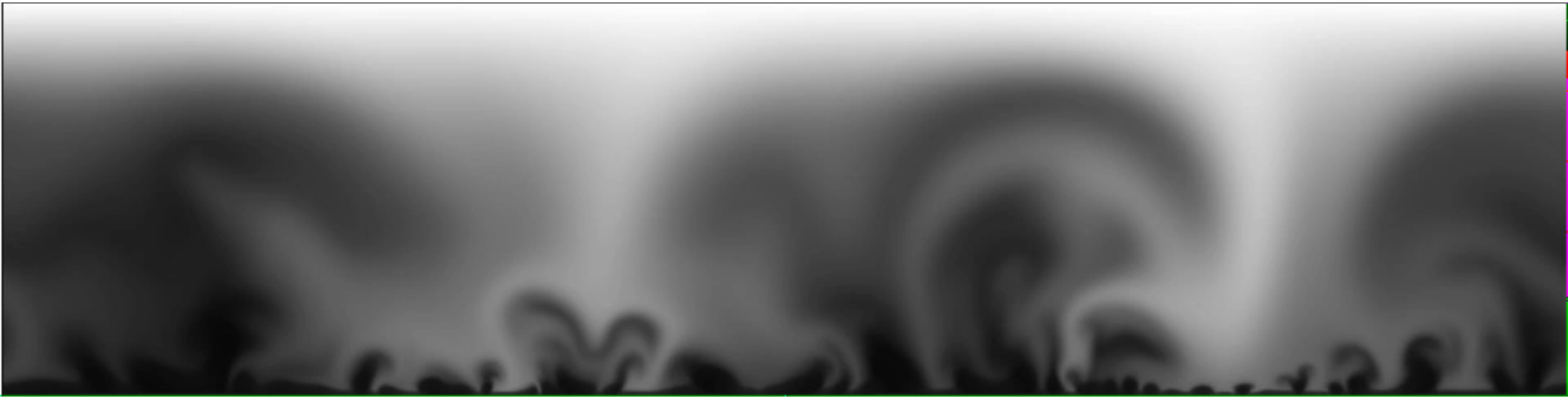
$$\rho\left(\frac{\partial \vec{u}}{\partial t} + \vec{u}.\nabla\vec{u}\right) = -\nabla p + \eta\nabla^2\vec{u} + \rho_e\vec{E}$$

Navier-Stokes equation

$$\varepsilon_w \nabla.\vec{E} = e\sum z_i c_i$$

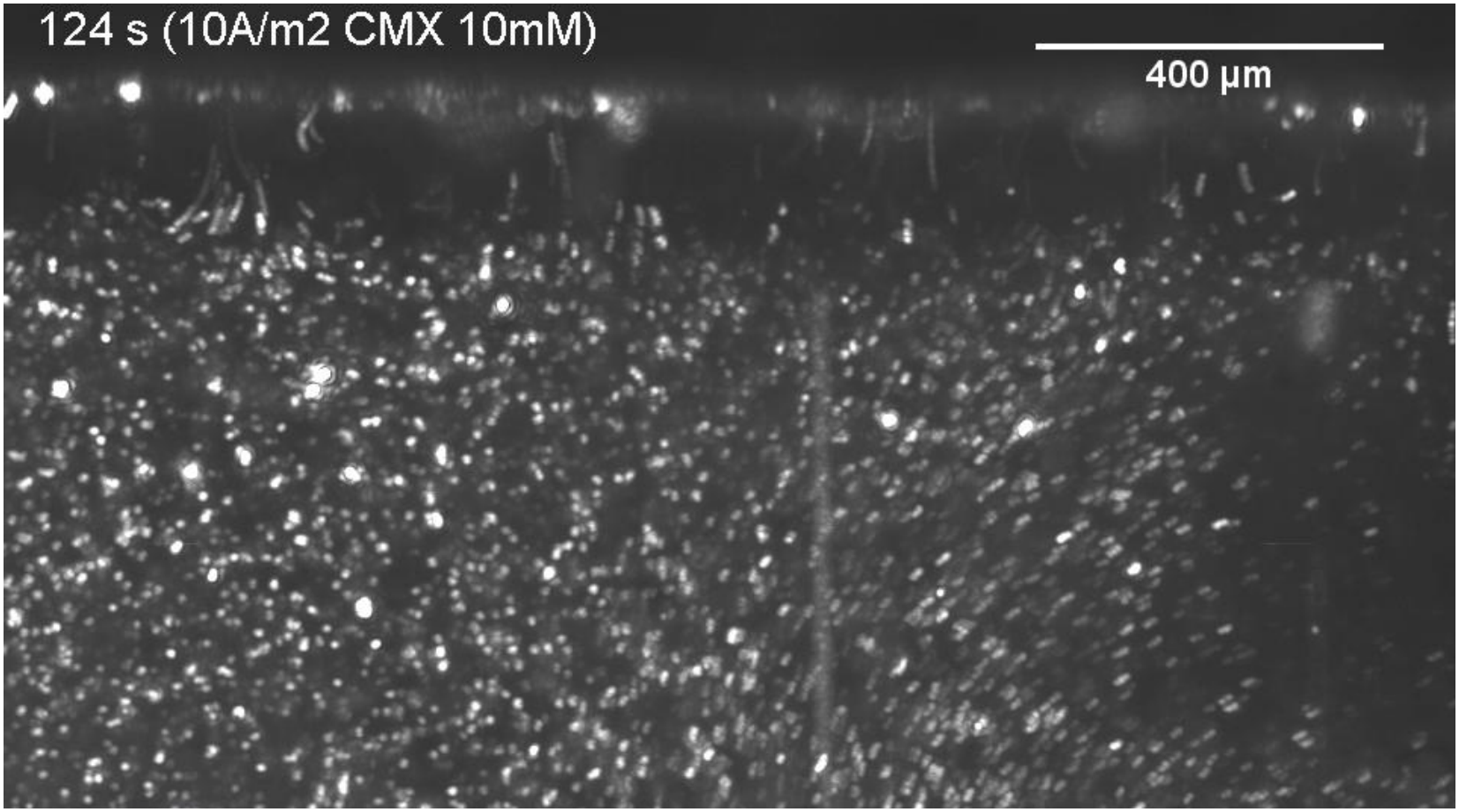
Poisson equation

Chaotic Behavior



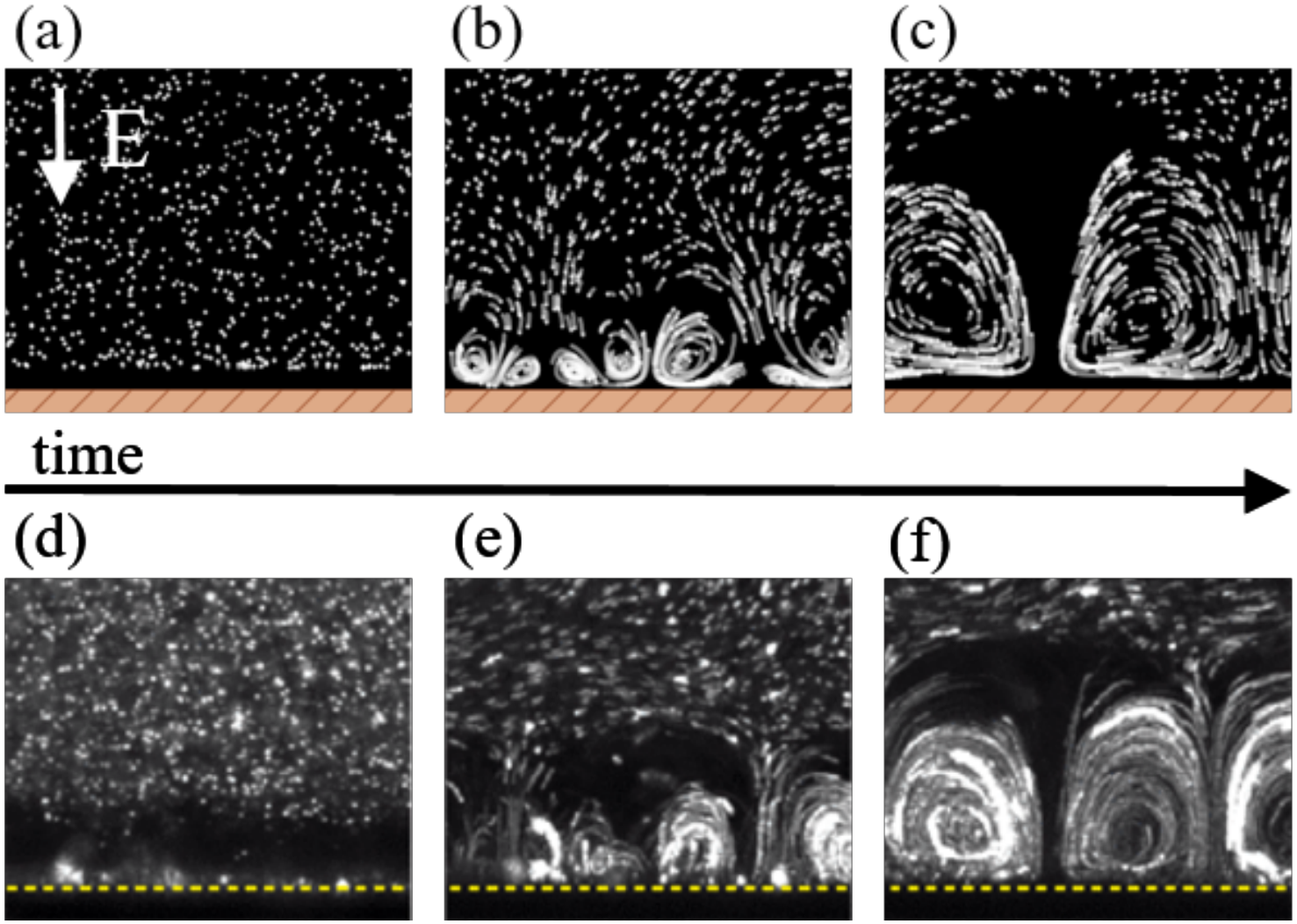
Ref: Druzgalski, Andersen, Mani, *Phys. of Fluids* (2013)

Recent Experimental Observation



de Valença, Wagterveld, Lammertink, Tsai PRE (2015)

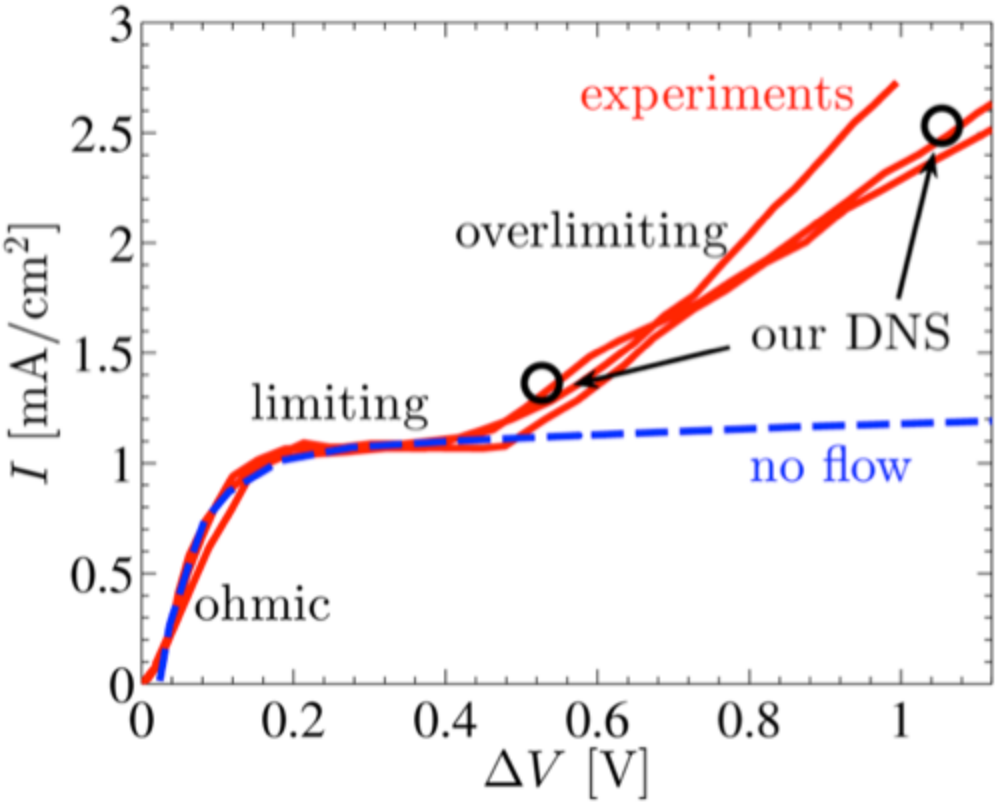
Comparison Between Experiments and Simulations



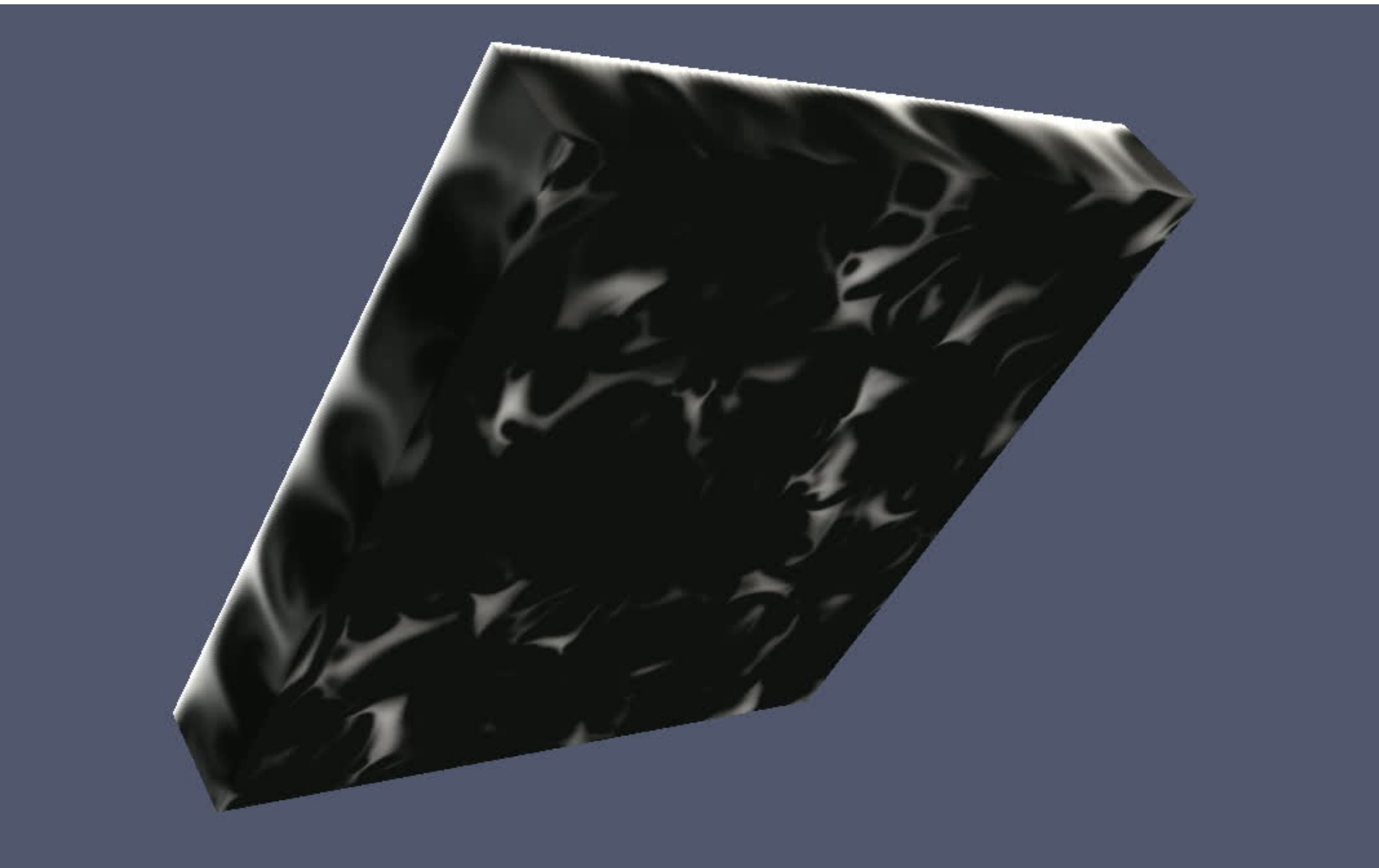
Simulations: Davidson, Wessling, Mani, Scientific Reports (2016)
Experiments: de Valença, Wagterveld, Lammertink, Tsai, Phys. Rev. E (2015)

Puzzle Explained

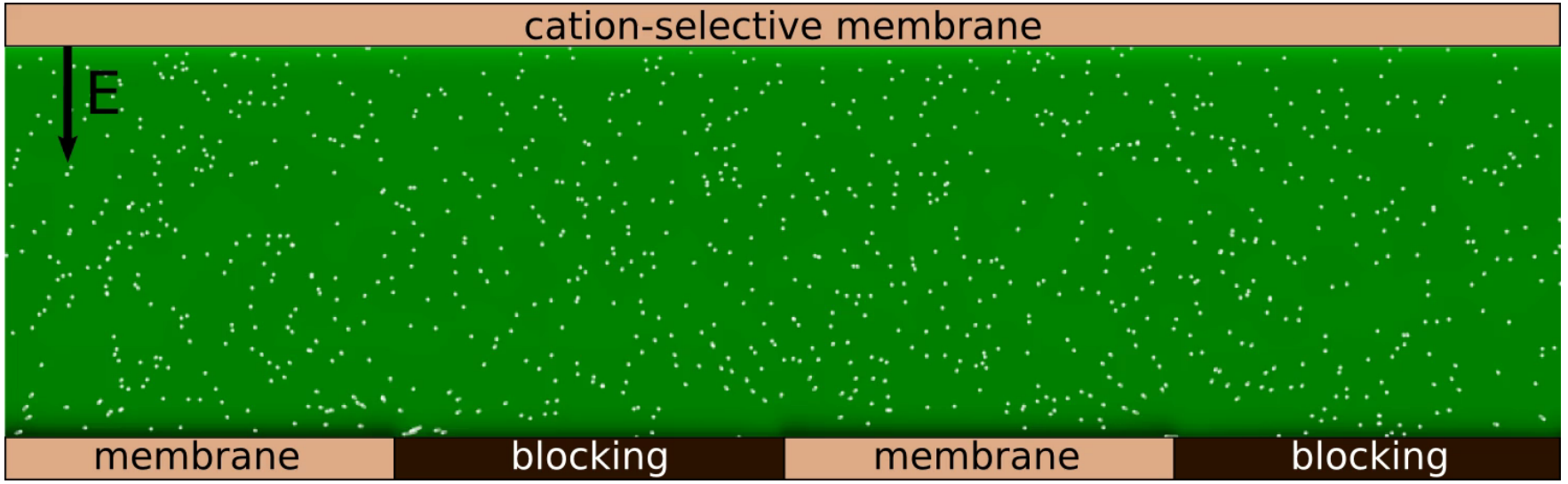
- **<u>Qualitative</u> comparison against Experiment**
  (experiment ref. Maleztki et al. 1992)

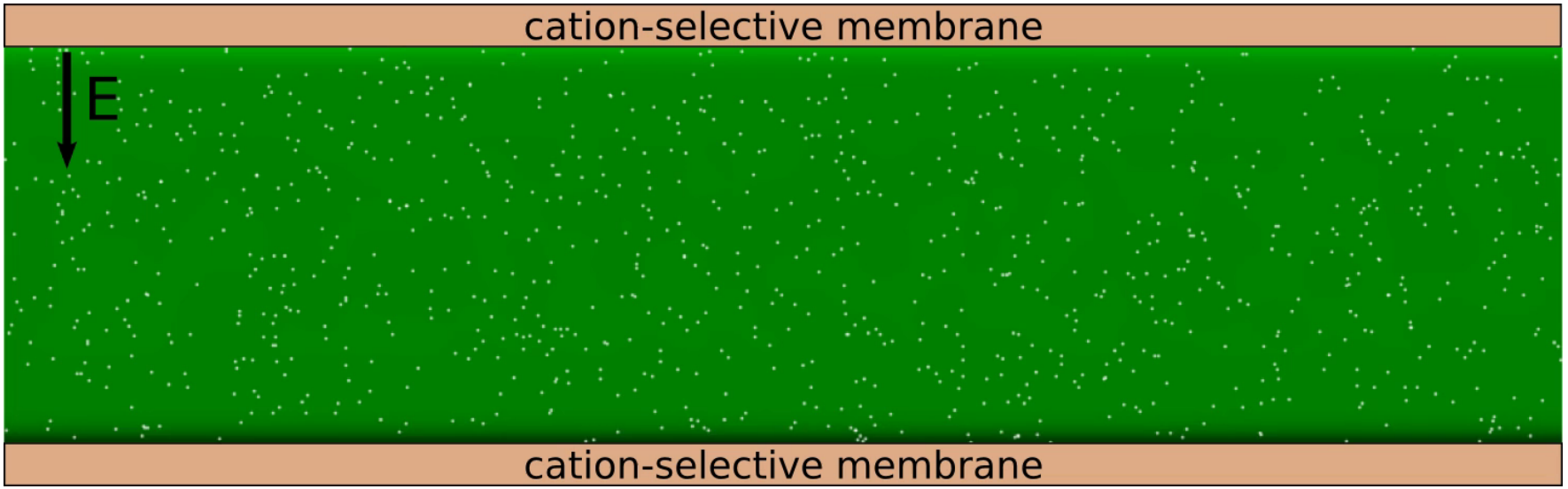


Direct Numerical Simulation in Three-dimensional Space



Impact of Membrane Patterning





Thank You

- **Refs:**
  - **Zamansky, R., Coletti, F., Massot, M., and Mani, A., "Radiation induces turbulence in particle-laden fluids," *Physics of Fluids,* 26, 071701, 2014.**
  - **Pouransari H. and Mani, A., "Effects of preferential concentration on heat transfer in particle-based solar receivers," *Solar Energy Engineering*, 139, 021008, 2017.**
  - **Druzgalski, C. L., Andersen, M. B., and Mani, A., "Direct numerical simulation of electroconvective instability and hydrodynamic chaos near an ion-selective surface," *Physics of Fluids*, 25, 110804, 2013.**
  - **Davidson, S. M., Wessling, M., and Mani, A., "On the dynamical regimes of pattern-accelerated electroconvection," *Scientific Reports,* 6, 22505, 2016.**