

# Enhanced Dispersion by Elastic Turbulent Flow Through Porous Media

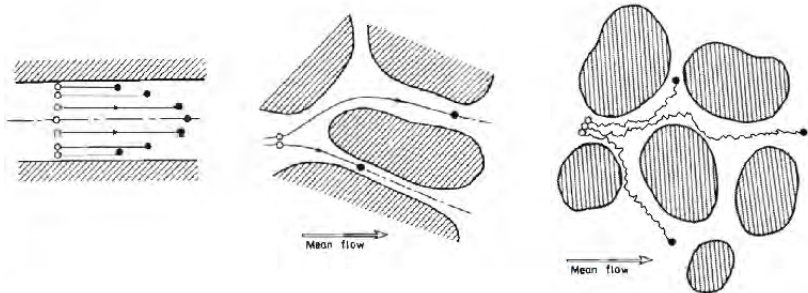
Christian Scholz, Frank Wirner, Juan Ruben Gomez-Solano,  
Clemens Bechinger

2.Physikalisches Institut  
Universität Stuttgart

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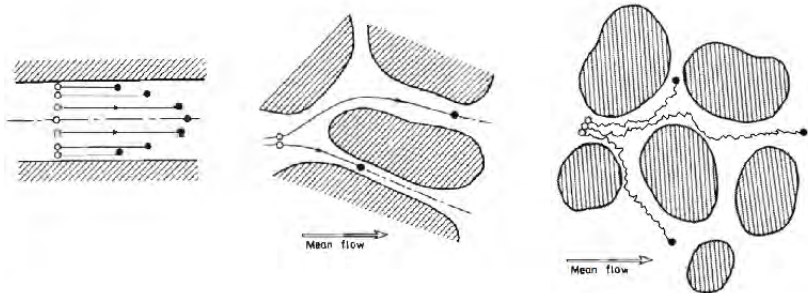


Dispersion = Spreading of Molecules/Particles in  
Porous Media Flow; Fried (1971), Bear (1972)



Small length scales - low Re - Laminar Stokes Flow

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However: For non-Newtonian Fluids: Turbulence at arbitrary small Re; Groisman and Steinberg, Nature (2000)

## Elastic turbulence in a polymer solution flow

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Department of Physics of Complex Systems, Weizmann Institute of Science,  
Rehovot 76100, Israel

Turbulence is a ubiquitous phenomenon that is not fully under-



Figure 3 Two snapshots of the flow at  $Wi = 13$ ,  $Re = 0.7$ . The flow under the black upper plate is visualized by seeding the fluid with light reflecting flakes (1% of the

Multimedia: Fluids: The Basics of Rheology for Scientists (PDF) Archived: [http://www.chemeddl.org/](#)

Elastic response depends on Weissenberg Number  $Wi = \dot{\gamma} \cdot \lambda$

Elastic Turbulence found for  $Wi > 1$

Nonlinear fluids appear in the majority of porous media applications

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M. Groisman, V. Steinberg, The Physics of Fluids, 2000, Vol. 12, No. 1, pp. 1-10

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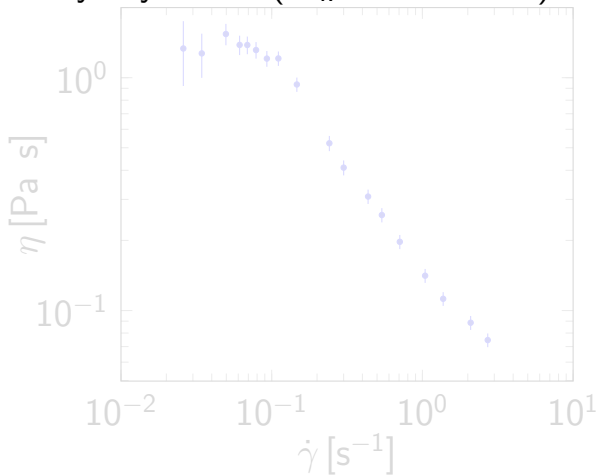
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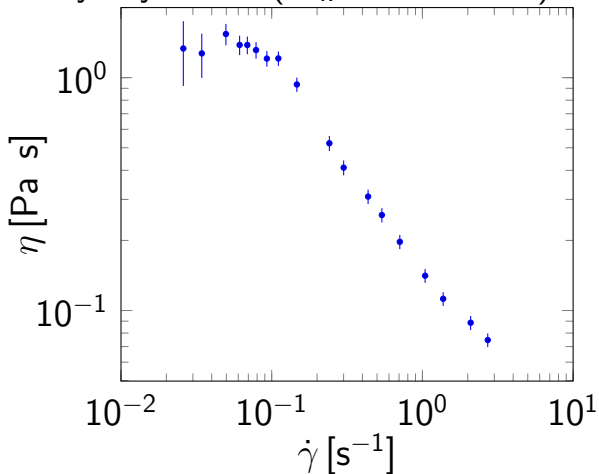


# Non-Newtonian Fluids

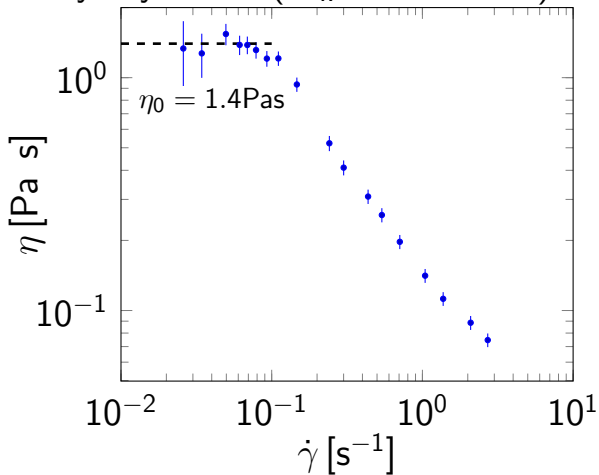
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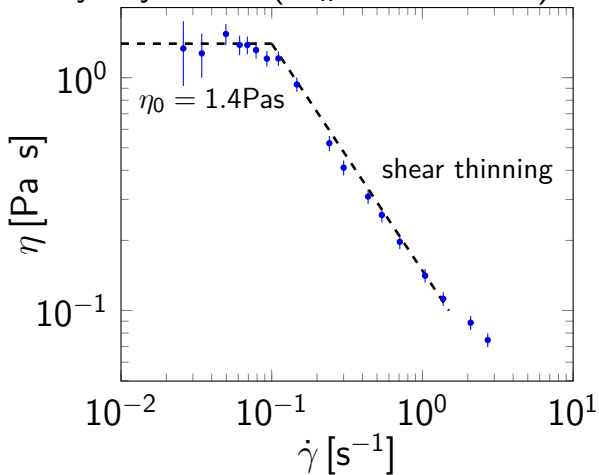


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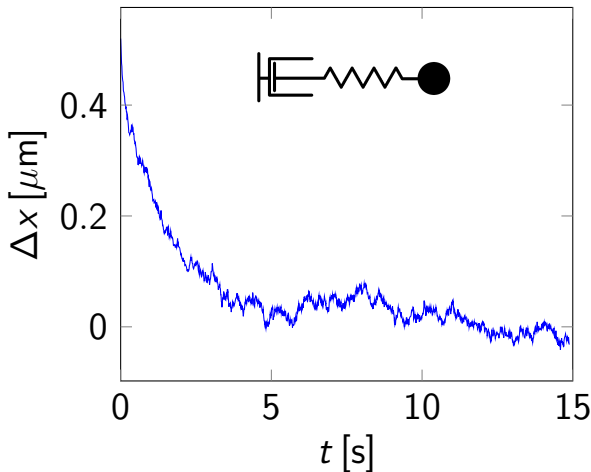
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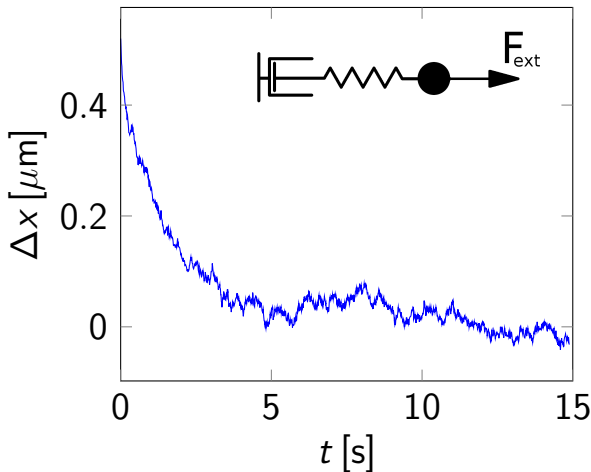
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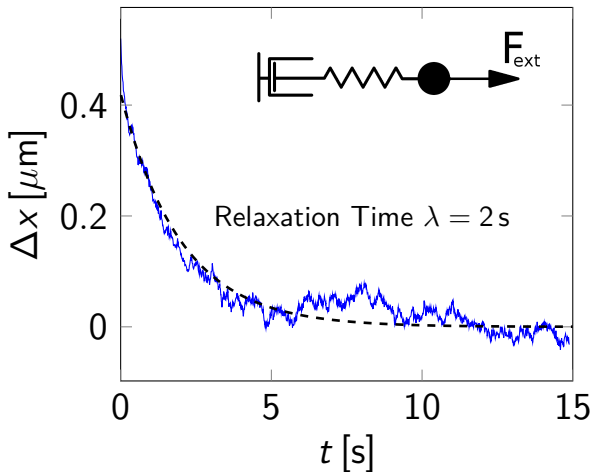
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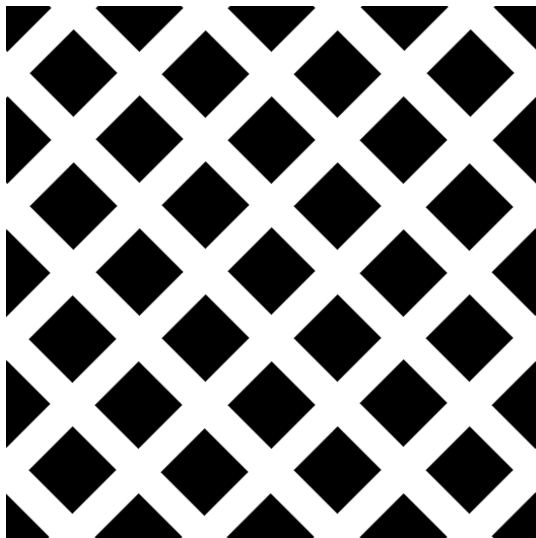
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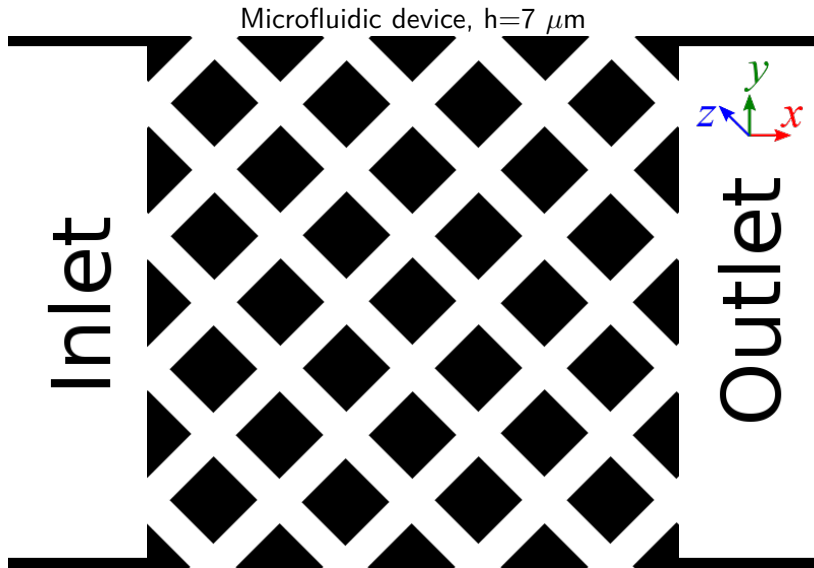
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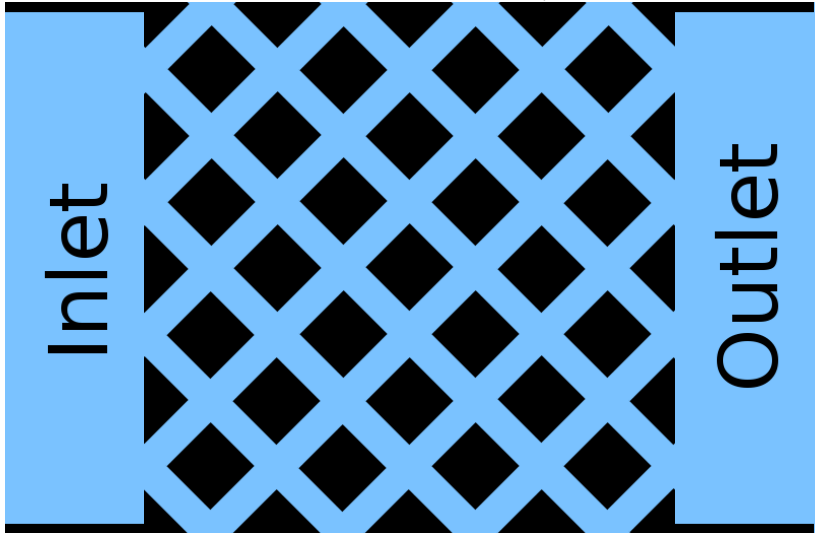




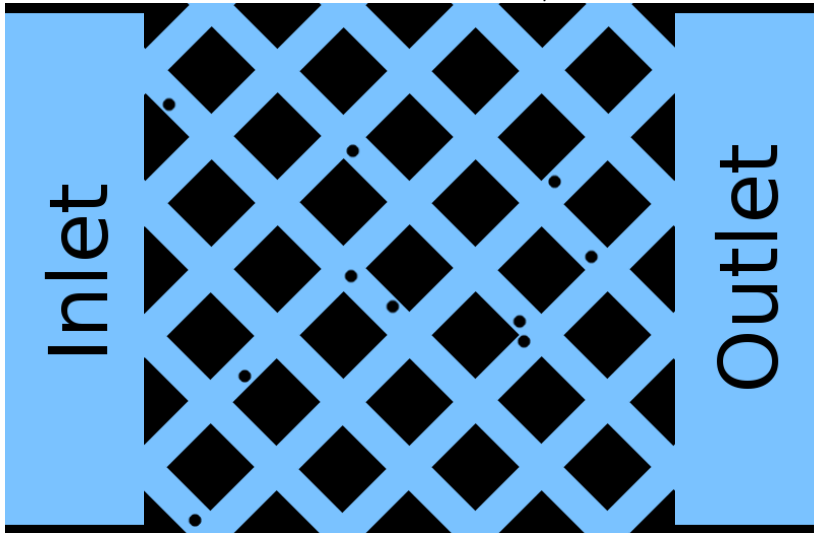




Microfluidic device,  $h=7\ \mu\text{m}$

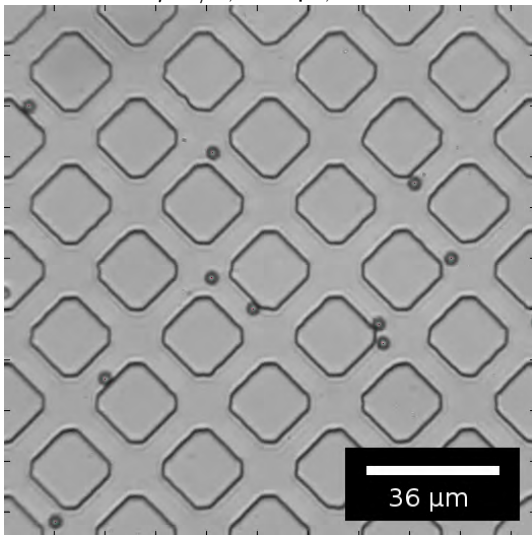


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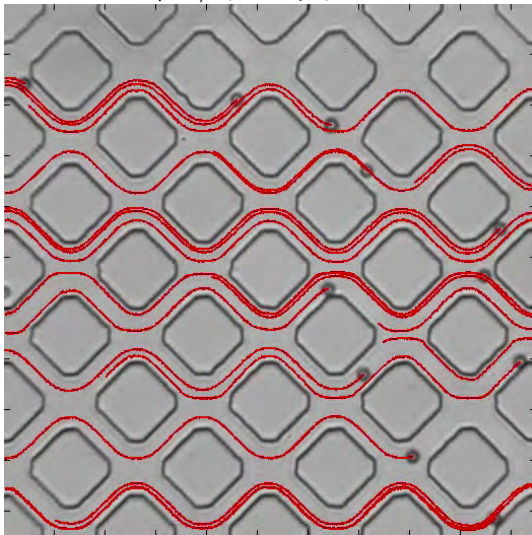
# Laminar Flow - H<sub>2</sub>O

$\bar{v} = 90 \mu\text{m/s}$ , 400fps,  $\text{Re} < 10^{-5}$



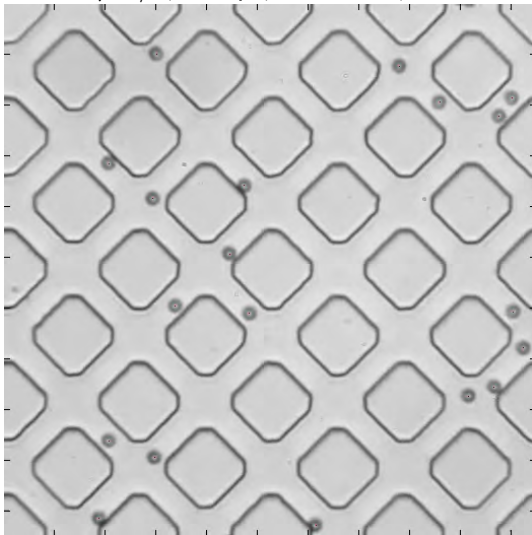
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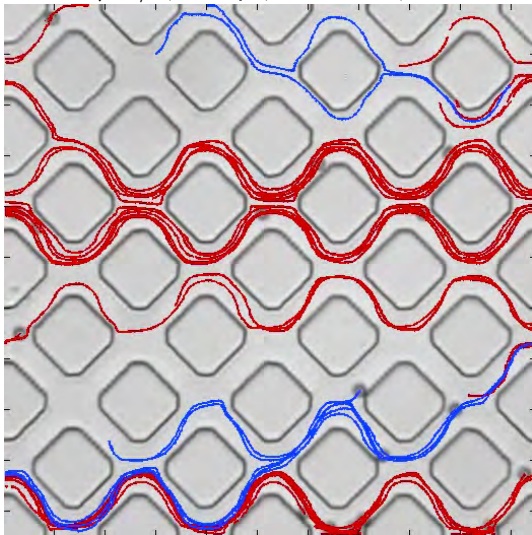
# Elastic Turbulence - PAAm

$\bar{v} = 100 \mu\text{m/s}$ , 400fps,  $Wi = 400$ ,  $Re < 10^{-5}$

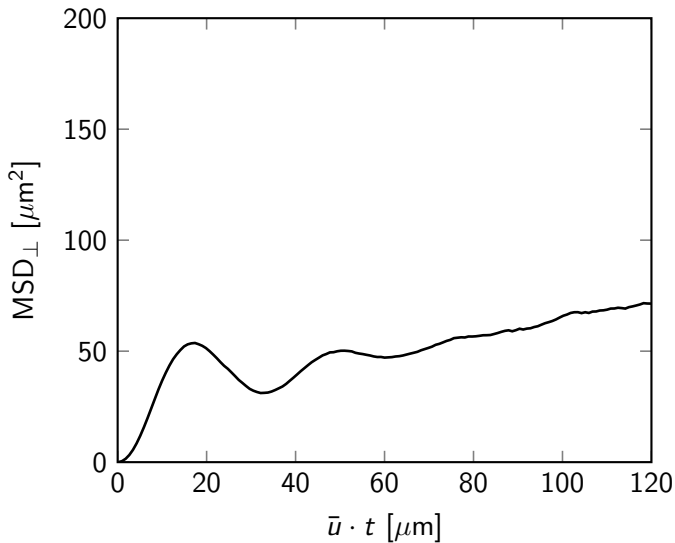


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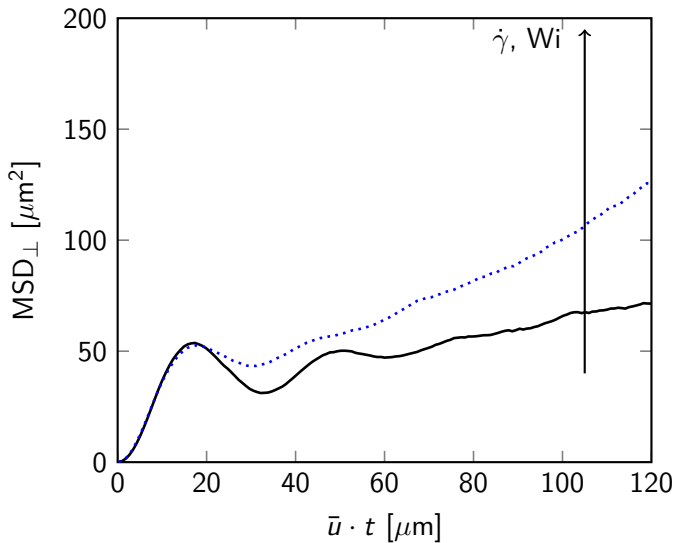


# Mean Squared Displacement

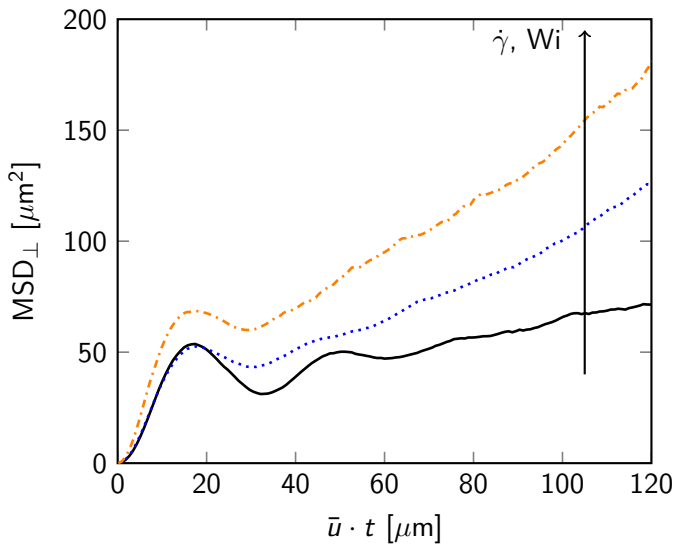




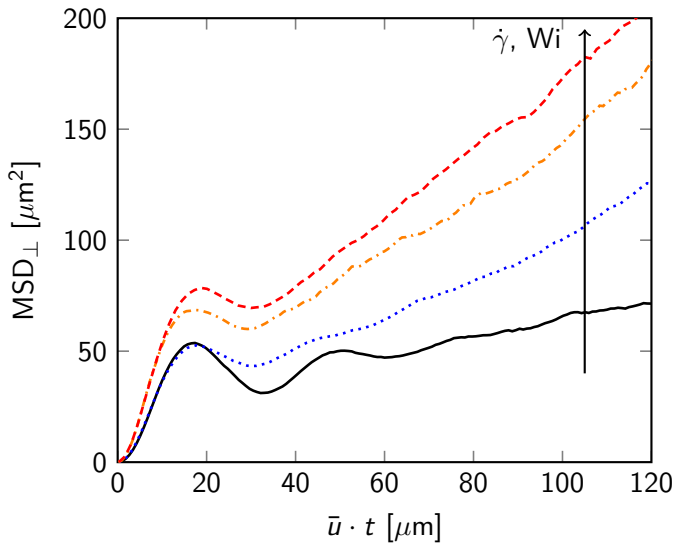
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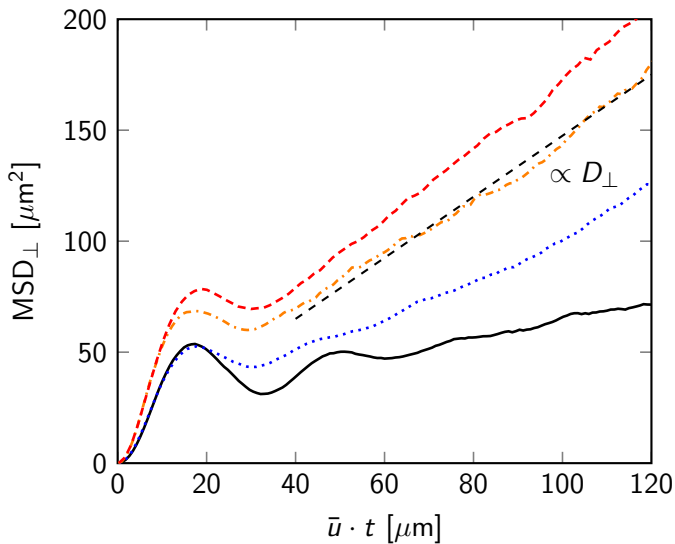
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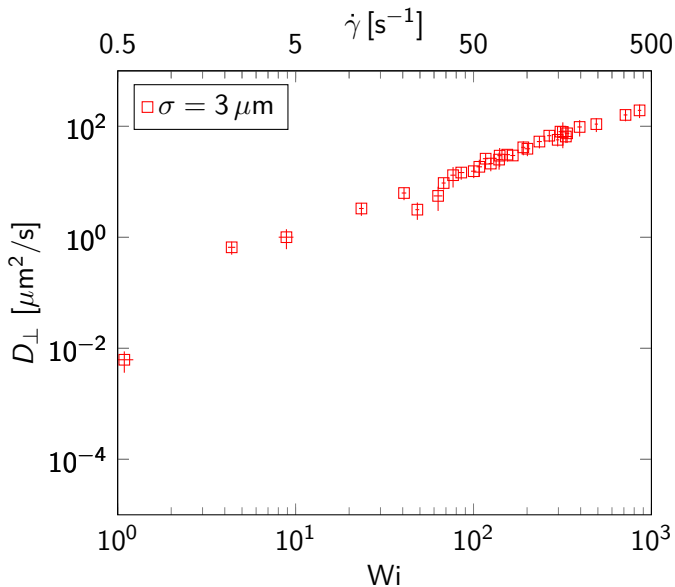
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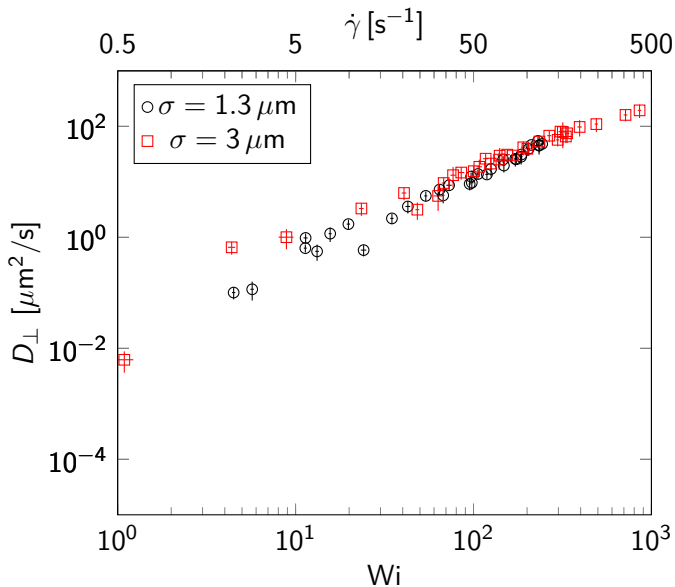
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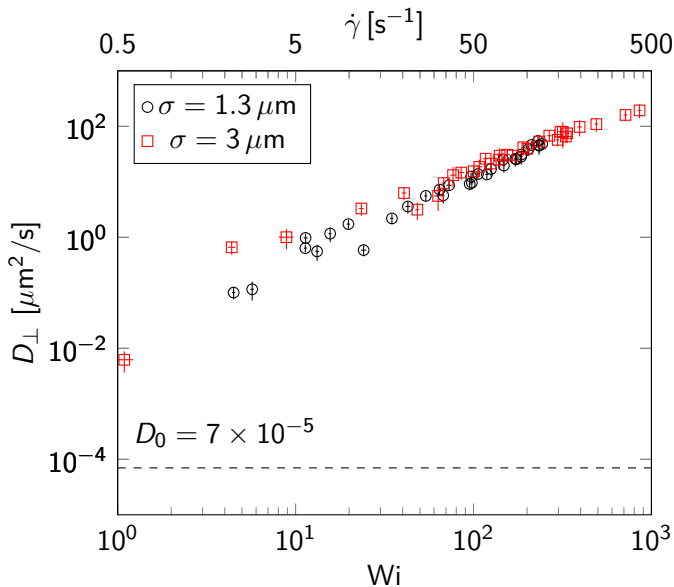
# Dispersion Coefficient



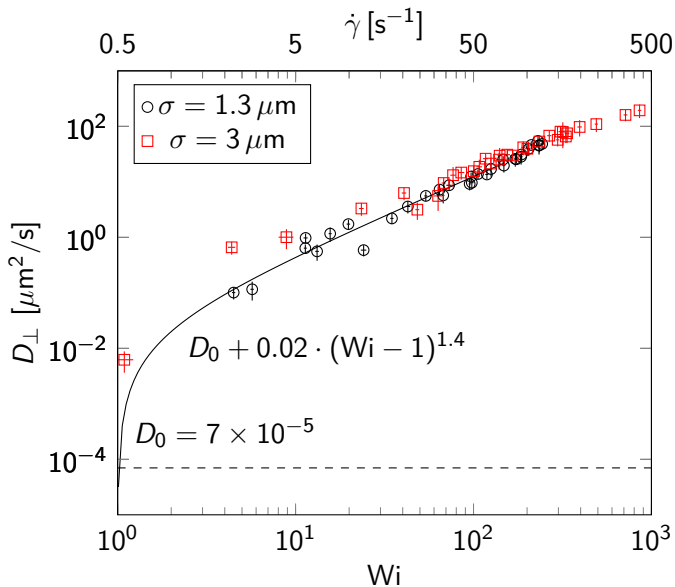
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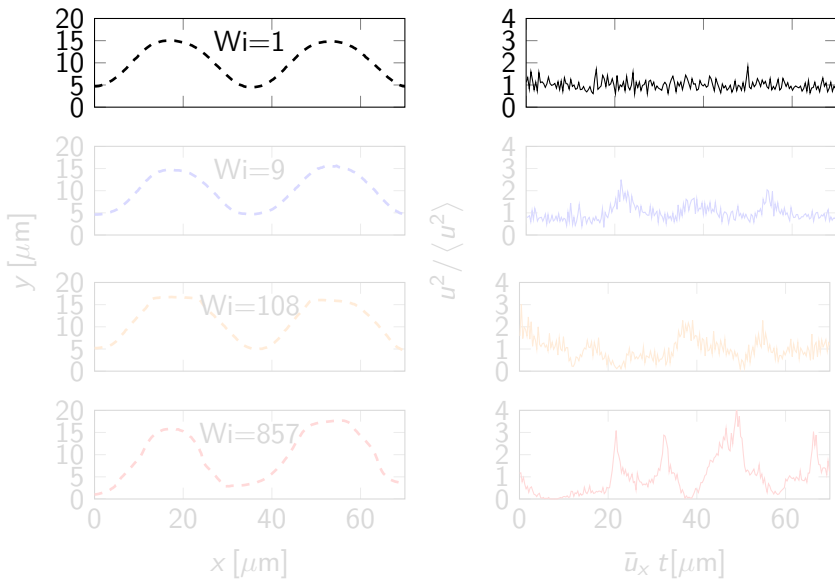


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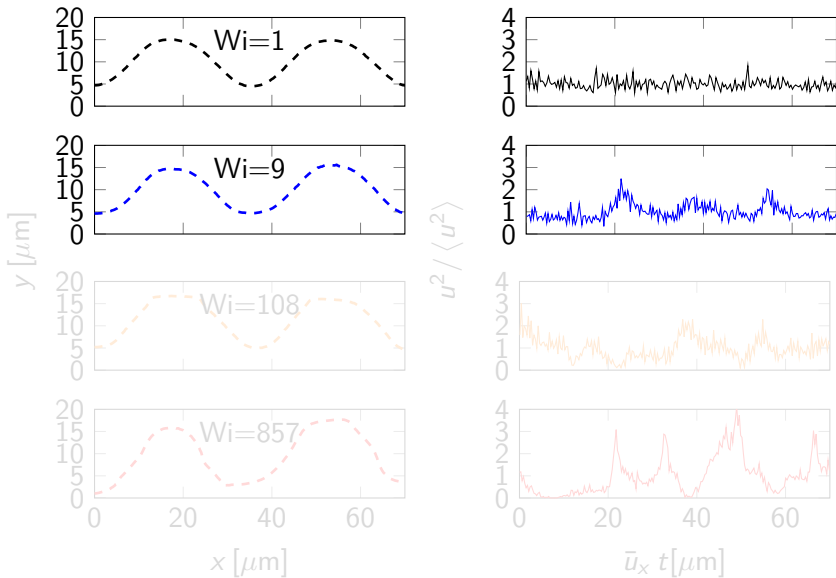




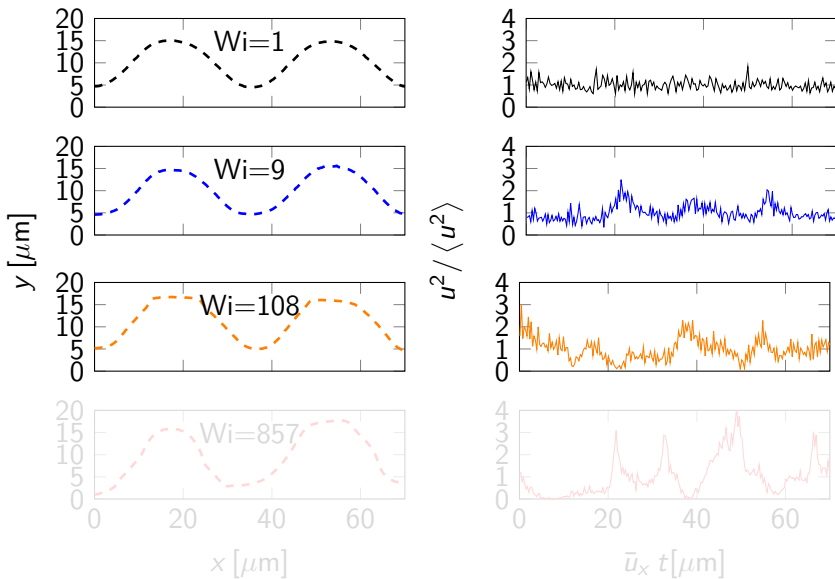
# Velocity Fluctuations



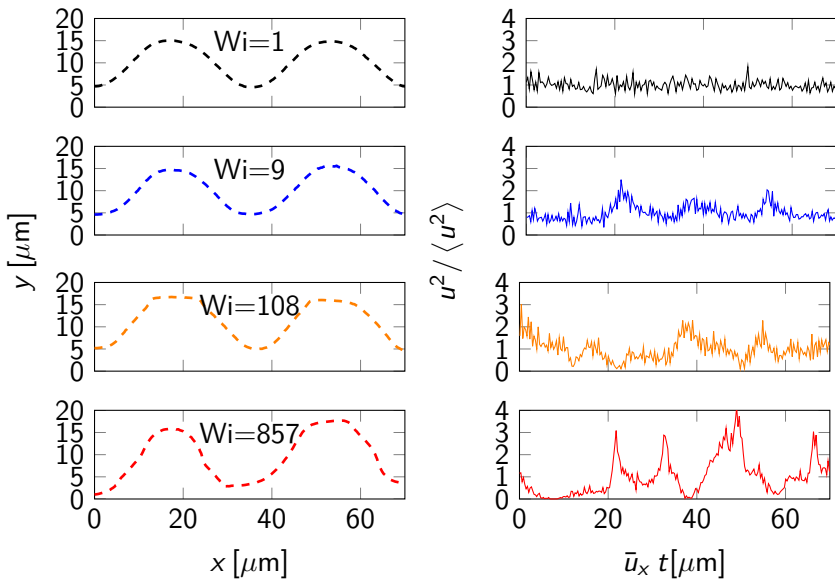
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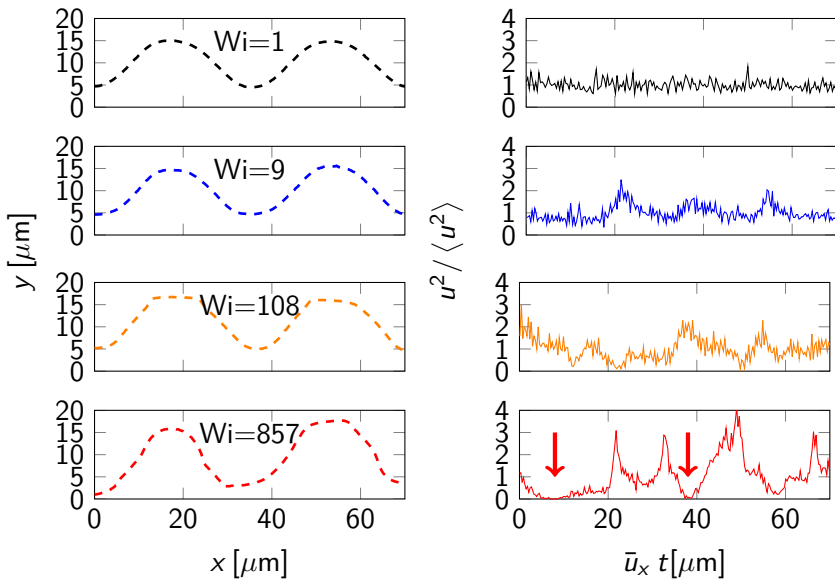
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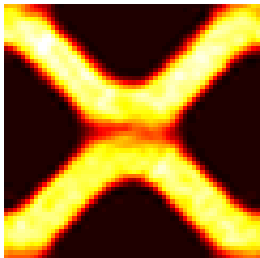


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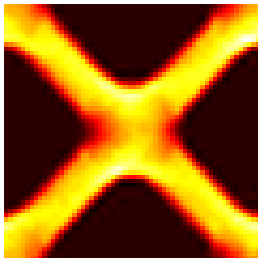


# Morphology of Flow Fields

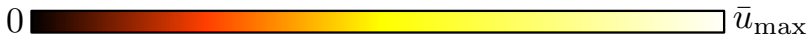
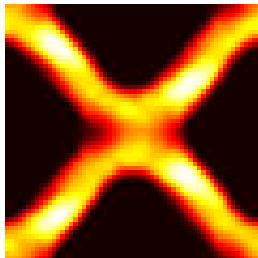
Wi=1



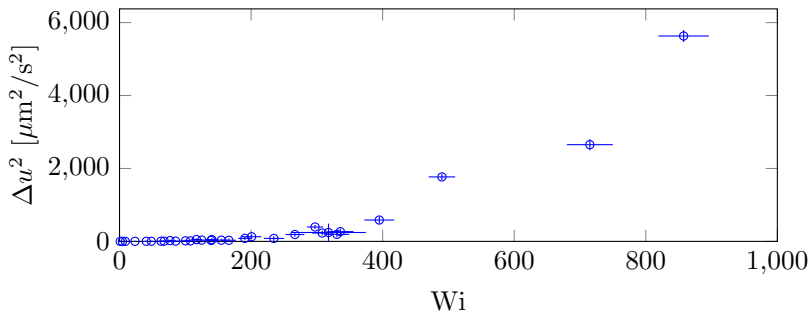
Wi=108



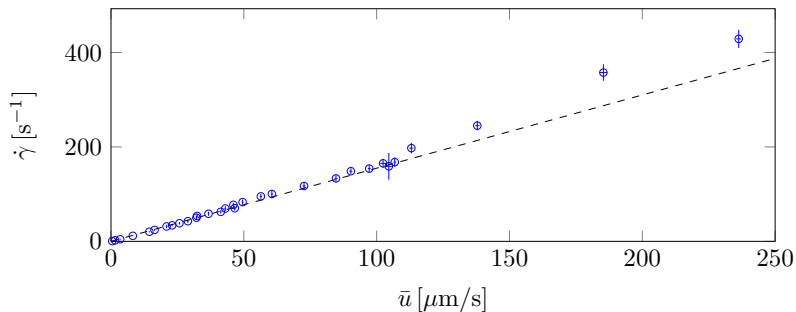
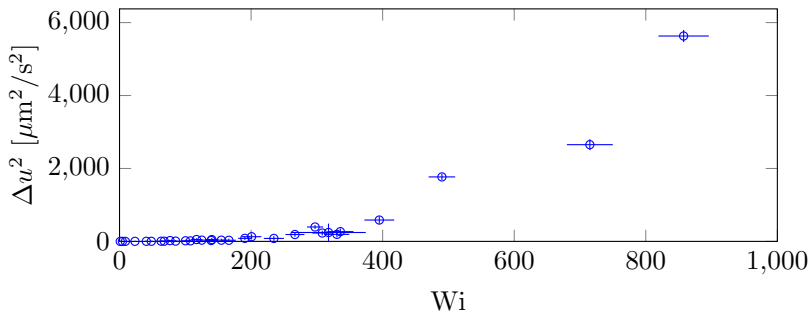
Wi=857



# Morphology of Flow Fields



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Elastic Turbulence



massive enhancement of dispersion in porous  
structures

Thank you for your attention