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Dispersion and Stretching in a 3D Porous media

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HAL Authorization

Dispersion & stretching in 3D porous media

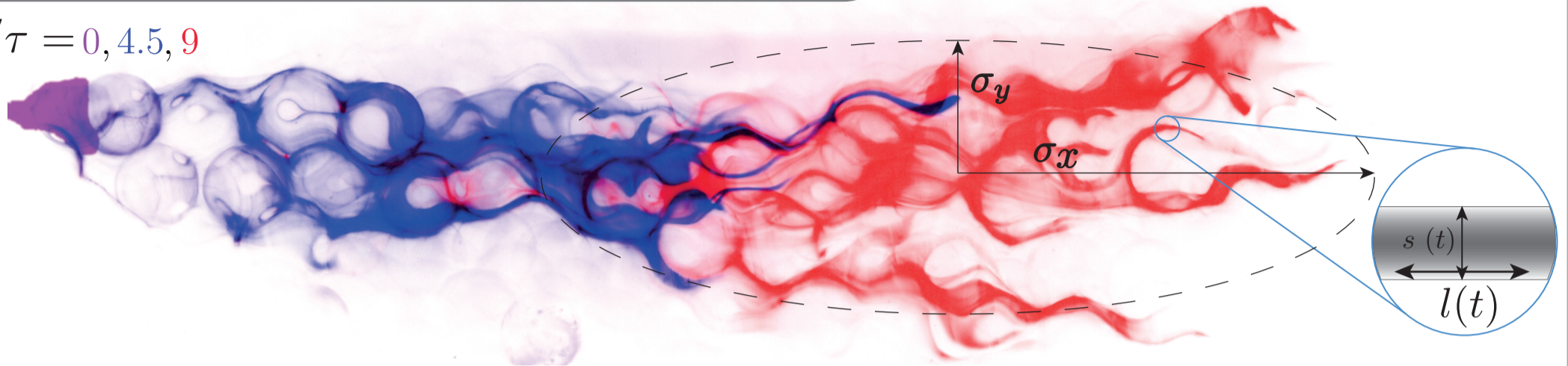
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Mixing of a blob of dye in a porous media

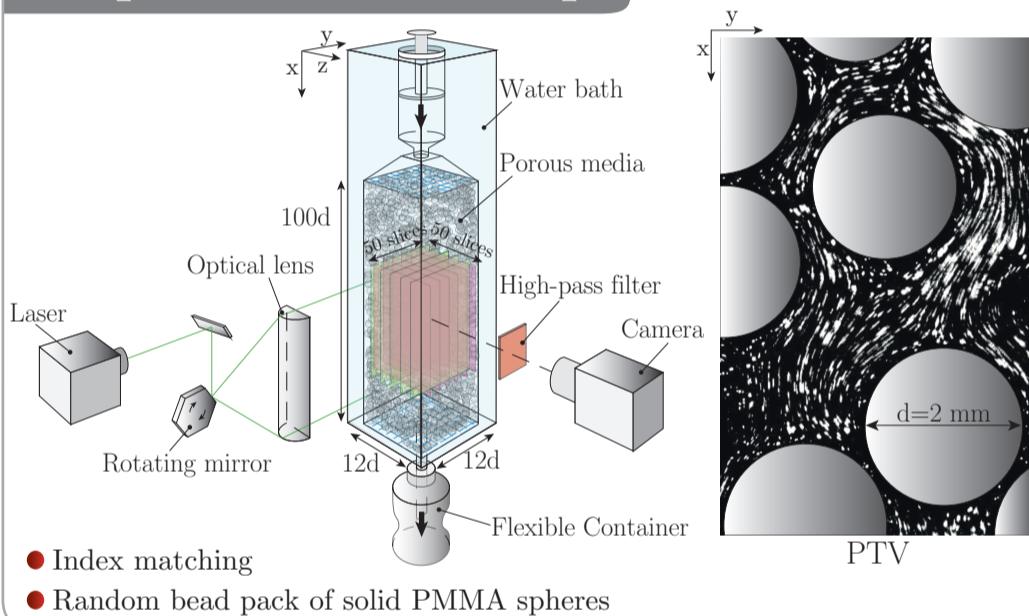
$t/\tau = 0, 4.5, 9$



A blob of dye advected in a 3D porous medium disperses in the surrounding medium while deforming into a set of elongated lamellae. We measure the 3D velocity field to characterize the dynamics of dispersion and stretching, thus investigating :

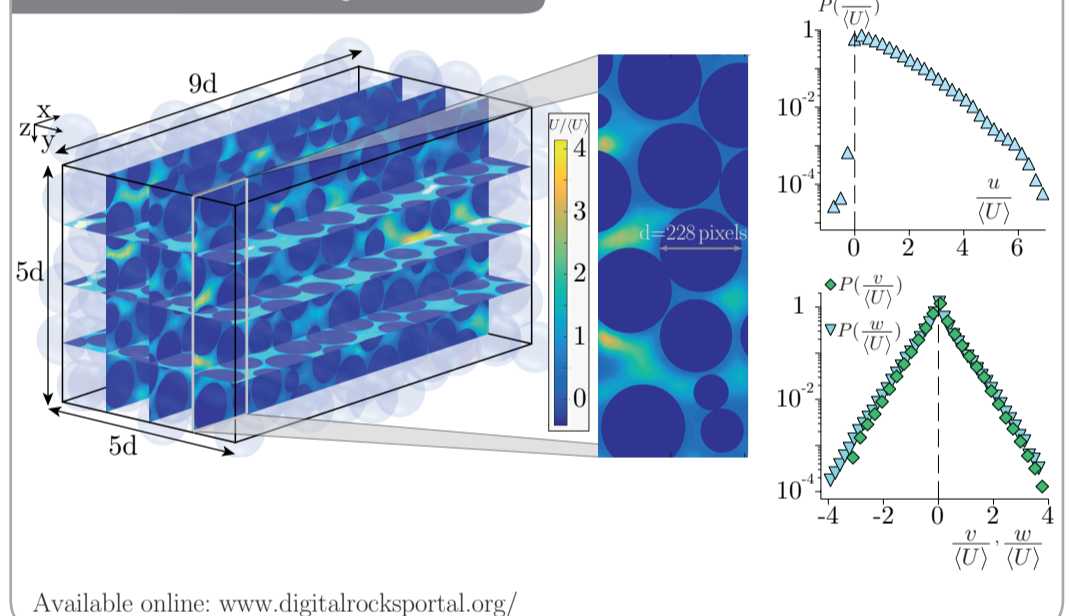
- What is the distribution of stretching $\rho (= \frac{l(t)}{l_0})$ in a 3D porous medium ?
- How is the velocity field distribution related to dispersion ?

Experimental set-up



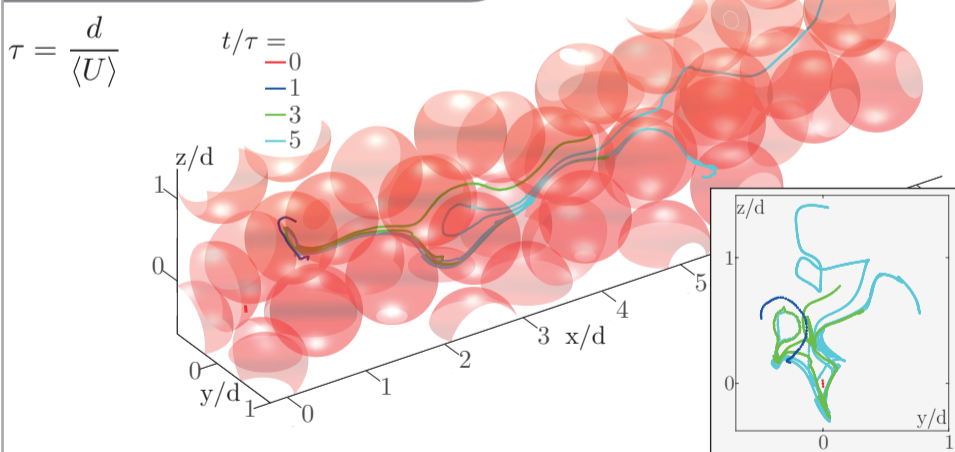
- Index matching
- Random bead pack of solid PMMA spheres

3D Velocity field

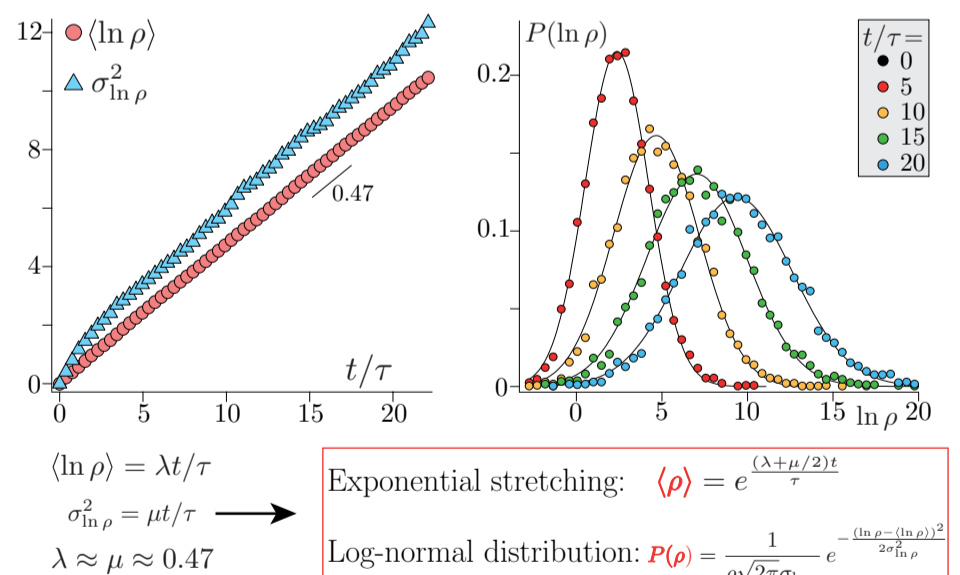


Available online: www.digitalrockportal.org/

Stretching laws



Evolution of a material line advected numerically in the 3D experimental velocity field

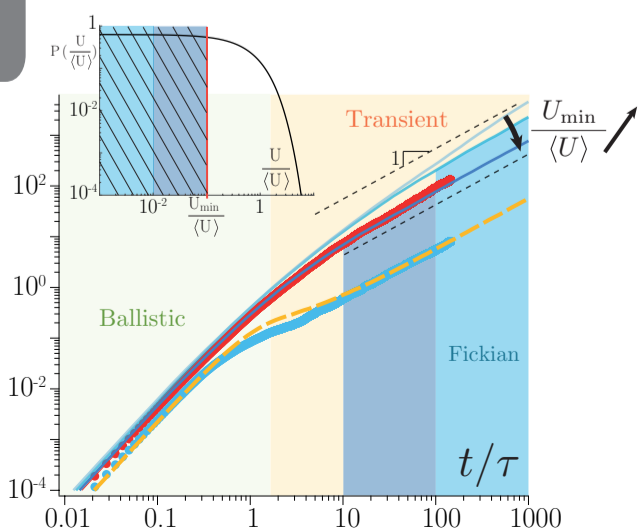


Exponential stretching: $\langle \rho \rangle = e^{\frac{(\lambda + \mu/2)t}{\tau}}$
 Log-normal distribution: $P(\rho) = \frac{1}{\rho \sqrt{2\pi} \sigma_{\ln \rho}} e^{-\frac{(\ln \rho - \langle \ln \rho \rangle)^2}{2\sigma_{\ln \rho}^2}}$

Dispersion

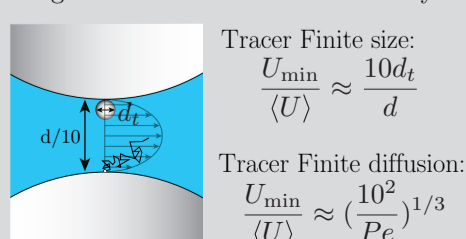
σ_x^2/d^2		
••• Experiments		
CTRW	$U_{\min}/\langle U \rangle$	t_F/τ
—	0	∞
—	0.01	100
—	0.1	10

σ_y^2/d^2		
••• Experiments		
—	CTRW with anti-correlation	



- Continuous Time Random Walk for a flat velocity distribution leads to **anomalous** dispersion $\rightarrow \frac{\sigma_x^2}{d^2} \sim \frac{\log(t/\tau)t}{\tau}$
- Minimum cut-off velocity in real system partially precludes the velocity distribution, leading to :

Origin of a minimum cut-off velocity :



Fickian behavior beyond: $t_F = d/U_{\min}$

$$\rightarrow \frac{\sigma_x^2(t)}{d^2} = \ln \left(\frac{\langle U \rangle}{U_{\min}} \right) \frac{\langle v_x \rangle^2 t}{\langle U \rangle^2 \tau}$$

$$\rightarrow \frac{\sigma_y^2(t)}{d^2} = \ln \left(\frac{\langle U \rangle}{U_{\min}} \right) (1-p) \frac{\langle v_y \rangle^2 t}{\langle U \rangle^2 \tau}$$