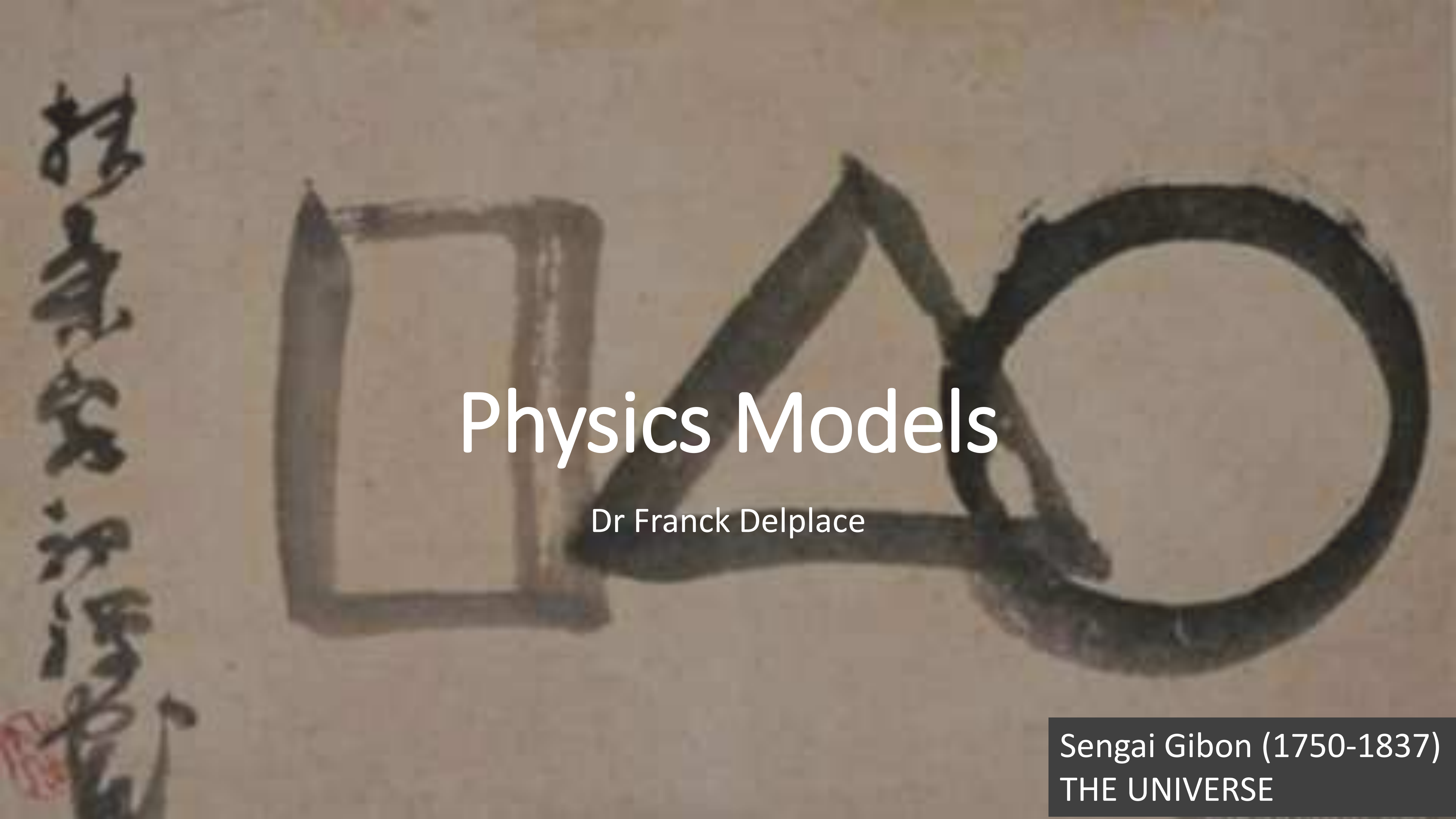
Physics Models

Dr Franck Delplace



Sengai Gibon (1750-1837)
THE UNIVERSE

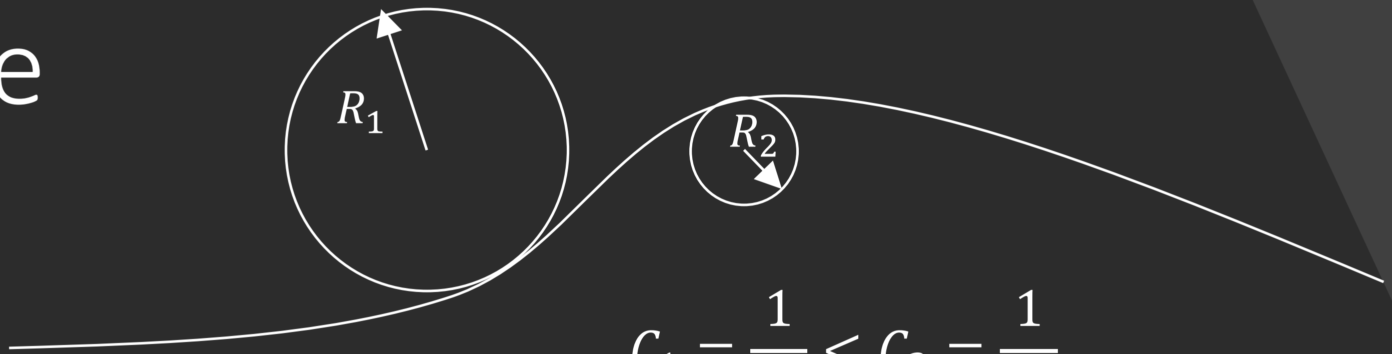
Transport Phenomena : Diffusion (3D)

Heat : Fourier	Matter : Fick	Momentum : Newton-NS	Dimensionless
• $\frac{\partial \vartheta}{\partial t} = \alpha\ \Delta\vartheta$	• $\frac{\partial C}{\partial t} = \beta\ \Delta C$	• $\frac{\partial \vec{V}}{\partial t} = \nu\ \Delta\vec{V}$	• $\frac{\partial f}{\partial t} = \lambda\ \Delta f$

Takahisa Okino (Oita Univ.) « Correlation between Diffusion Equation and Schrödinger Equation », 2013, J. Of Modern Physics, 4, 612-615.

Curvature

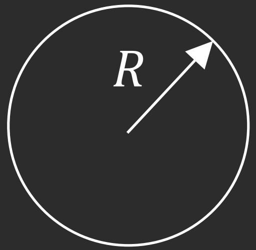
- For a Curve : 1D

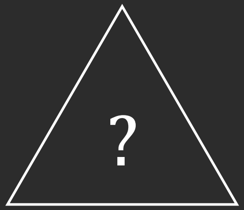


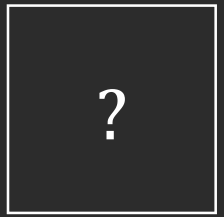
$$C_1 = \frac{1}{R_1} < C_2 = \frac{1}{R_2}$$

- For a Polygon : 2D

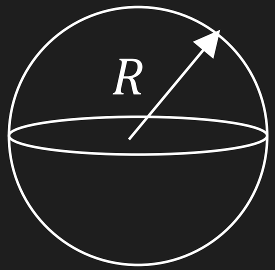
$$C_{2D} = \frac{1}{R}$$



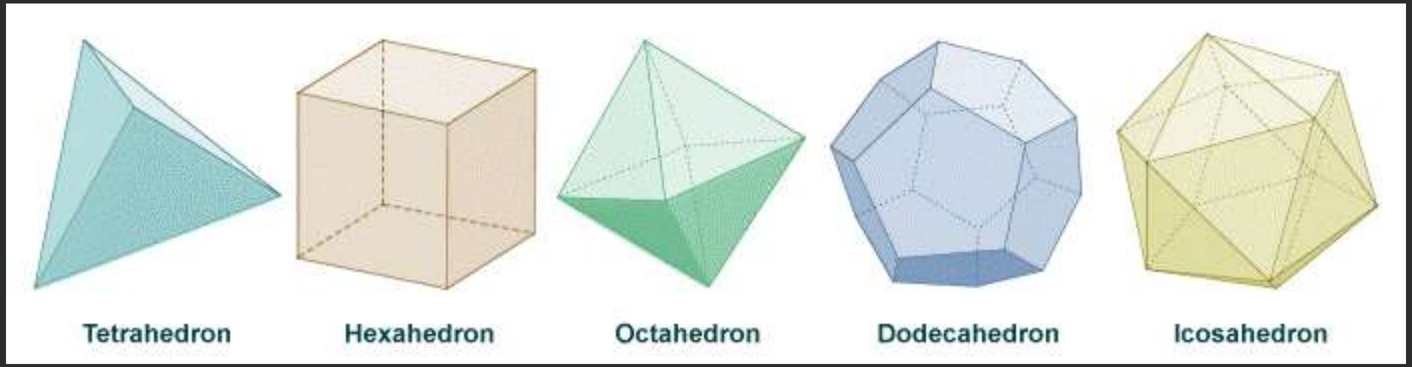




- For a polyhedra : 3D



$$C_{3D} = \frac{1}{R^2}$$



?

Curvature (Delplace 2017, IJSEAS)

- **2D**

$$C_{2D} = \frac{P}{2S}$$

P = Perimeter

S = Surface

- **3D**

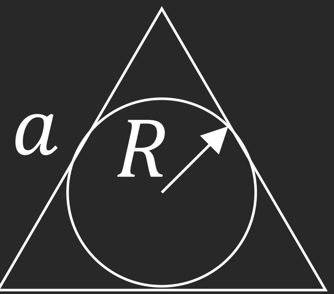
$$C_{3D} = \frac{S^2}{9V^2}$$

S = Surface

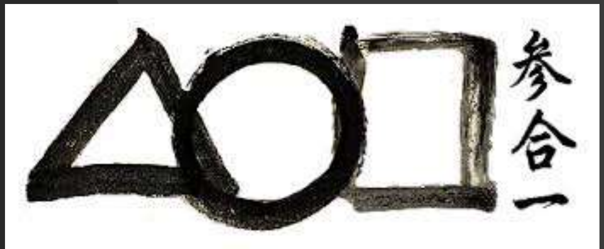
V = Volume

Examples For Regular Geometries

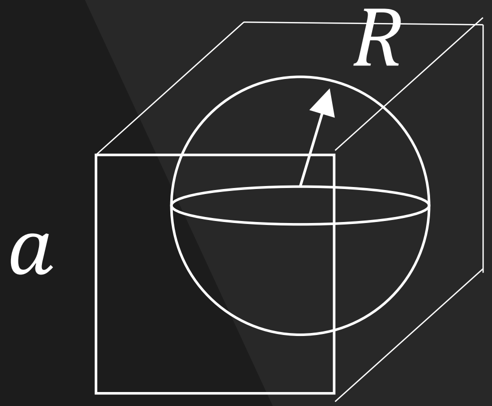
- 2D



$$C_{2D} = \frac{P}{2S} = \frac{2\sqrt{3}}{a} = \frac{1}{R} \Rightarrow R = \frac{a}{2\sqrt{3}}$$



- 3D



$$C_{3D} = \frac{S^2}{9V^2} = \frac{36a^4}{9a^6} = \frac{4}{a^2} = \frac{1}{R^2} \Rightarrow R = \frac{a}{2}$$

Laplacian and Curvature

- Self-Evident in 1D

$$\Delta f = \frac{\partial^2 f}{\partial x^2} = f''(x)$$

- Less evident in 3D

$$\Delta f = k\,C\left(\bar{f} - f\right)$$

Cube $$\Delta f = \frac{24}{a^2}\left(\bar{f} - f\right) = 6\,C\left(\bar{f} - f\right)$$

Physics is Curvature

- Transport Phenomena

$$\frac{\partial \theta}{\partial t} = \alpha\, k\, C\, (\bar{\theta} - \theta)$$

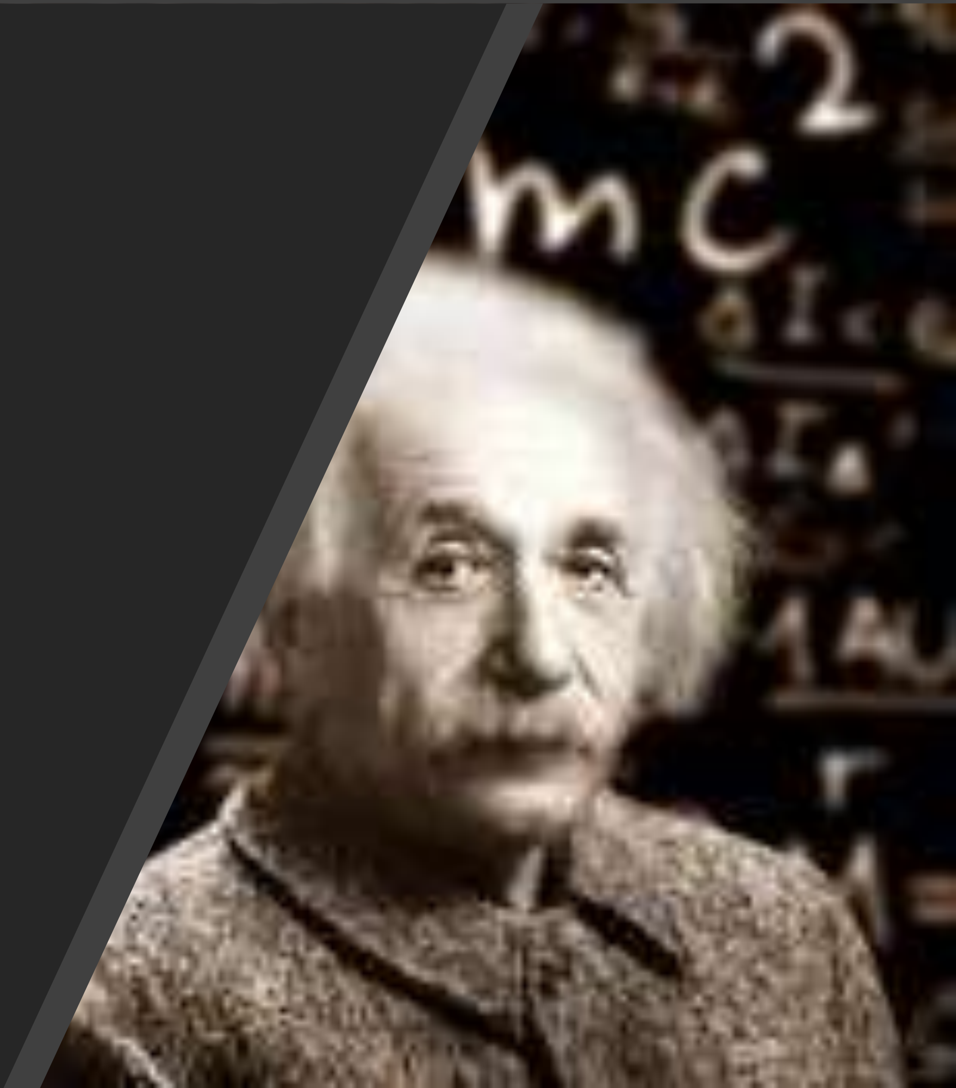
$$\frac{\partial C}{\partial t} = \beta\, k\, C\, (\bar{C} - C)$$

$$\frac{\partial \vec{V}}{\partial t} = \nu\, k\, C\, \left(\bar{V} - \vec{V}\right)$$

- Gravity

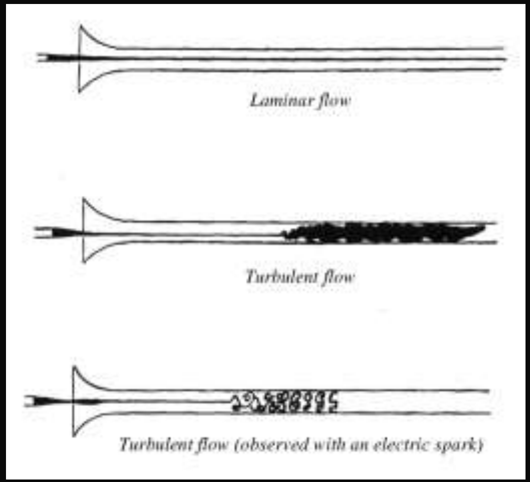
Einstein : Energy Density proportional to Space-Time CURVATURE

CURVATURE is a Major Quantity for Physics Models



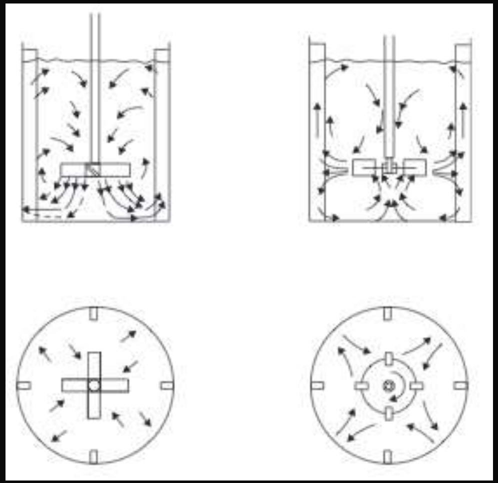
In Fluid Mechanics

- 2D



Tubular Flow

- 3D



Mixing

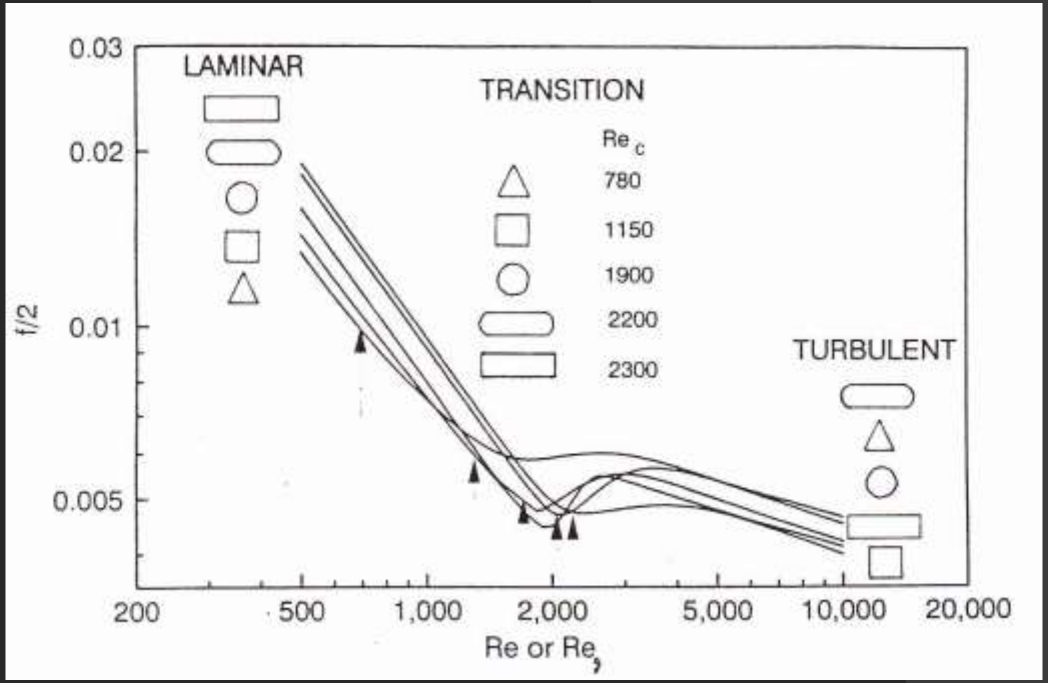
Osborne Reynolds 1842-1912

Reynolds Number and Curvature

- 2D : Flow in Ducts

$$Re = \frac{\rho \bar{V} D_h}{\eta} = \frac{\bar{V} D_h}{\nu} = \frac{\bar{V} 2R_h}{\nu} = \frac{2\bar{V}}{\nu} . \frac{1}{C_h} = \frac{C_f}{C_h}$$

Reynolds Number is the Ratio of Two Curvatures



For a Pipe of Circular Cross-Section

$$C = \frac{1}{R} \quad and \quad \bar{V} = \frac{Q}{\pi R^2}$$

$$Re = \frac{2}{\pi \nu} . C . Q$$

For a given Flow Rate Q and given kinematic viscosity ν Reynolds Number is Proportional to Cross-Section Curvature C

Reynolds Number and Curvature

- 2D : Flow in Ducts

For a duct of square cross-section

$$Re = \frac{1}{2\nu}.C.Q$$

For a duct of equilateral triangular cross-section

$$Re = \frac{2}{3\sqrt{3}\nu}.C.Q$$

For a given flow-rate Q and a given kinematic viscosity ν Reynolds number is proportional to cross-section curvature C

Reynolds Number and Curvature

- 3D : Mixing

$$Re_R = \frac{\rho N D^2}{\eta} = \frac{N D^2}{\nu} = \frac{4 N R^2}{\nu} = \frac{4N}{\nu}.\frac{1}{C} = \frac{C_f}{C}$$

Rotational Reynolds Number is the Ratio of two Curvatures

Considering that $\frac{4N}{\nu}$ is the 3D Flow Curvature and $\bar{\dot{\gamma}} = K_S\,.\,N$ we have $\bar{\dot{\gamma}} = \frac{K_S}{4}.\,C_f.\,\nu$

Proportionality between velocity gradient and curvature is a major general relationship !

Heat Transfer

- Increasing S enhances heat exchange

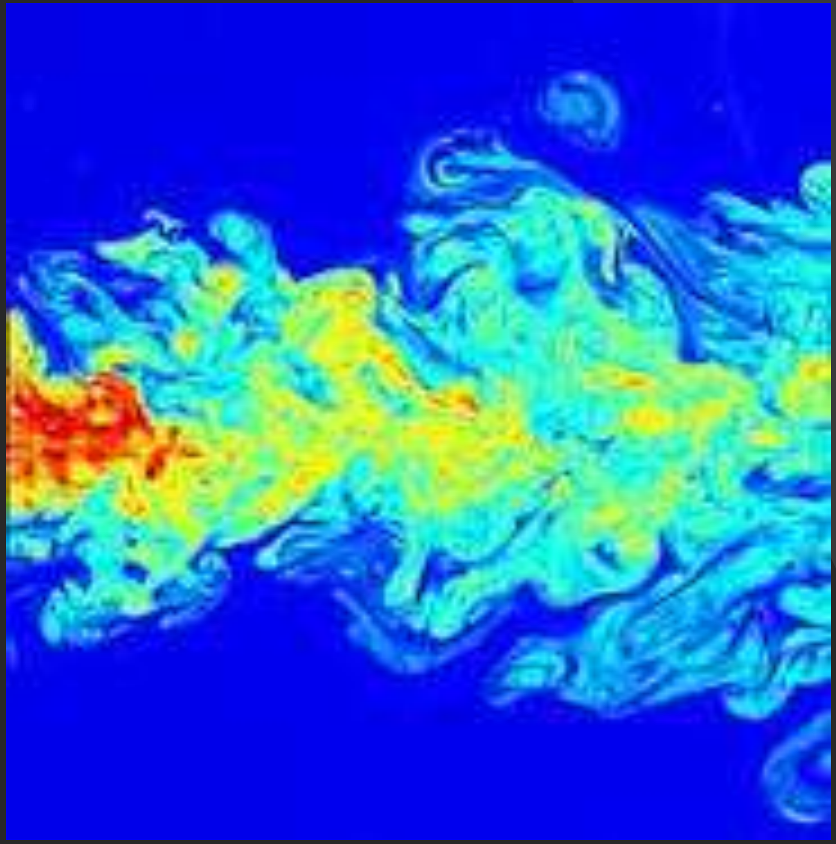
According to : $C_{3D} = \frac{S^2}{9V^2}$ - you increase S without changing V.

In agreement with “Hairy Ball” Mathematical Model.

Heat Transfer

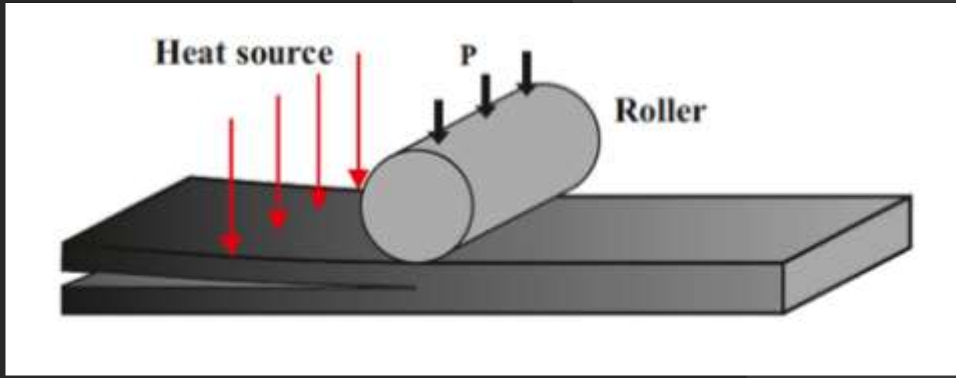
- Turbulence enhances heat transfer

Flow « Fractalization » increase S without changing V.

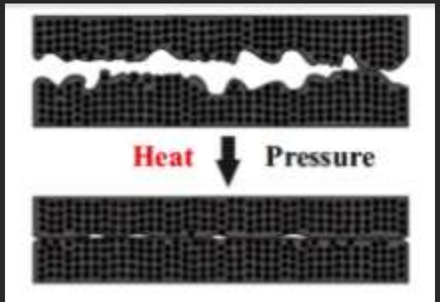


Heat & Momentum Transfers : Composites Consolidation (Prof. Chinesta and Dr Abisset-Chavanne)

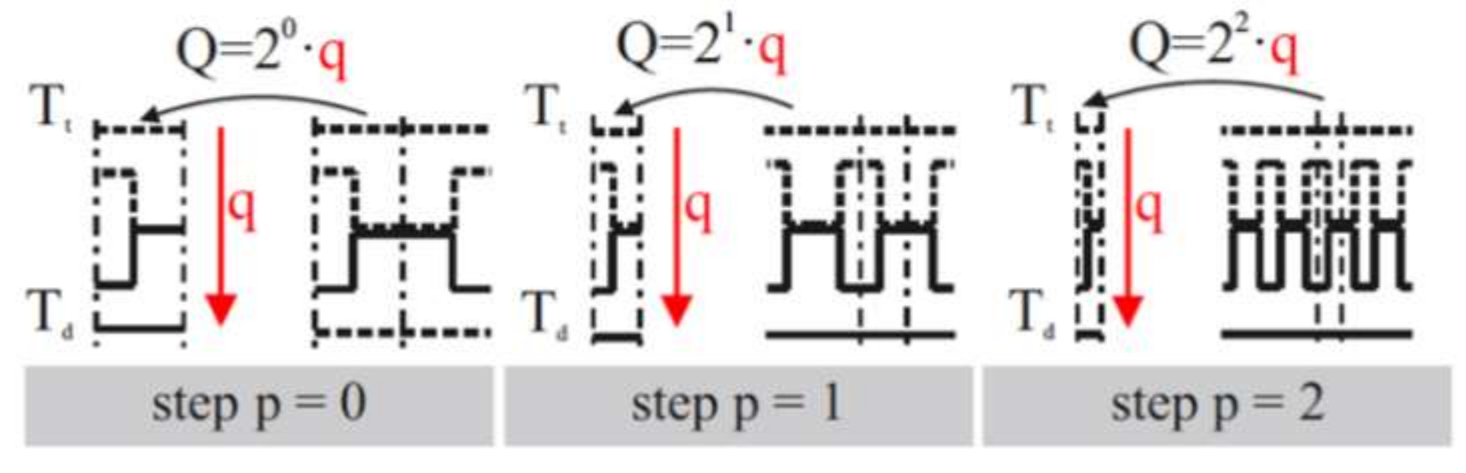
Both Heat and Pressure applied to composites sheets.



Interfaces irregularities disappear due to both heat and pressure giving polymer molecules rearrangement.

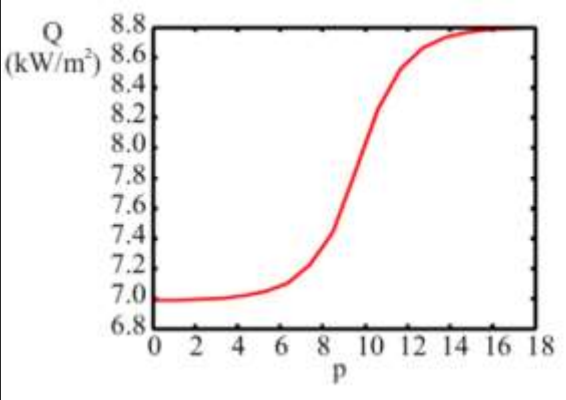


Heat & Momentum Transfers : Composites Consolidation



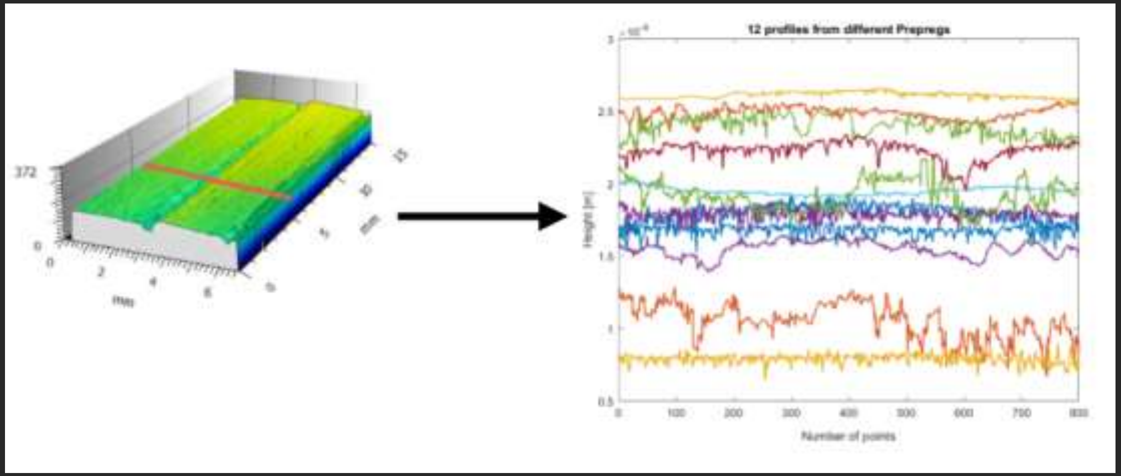
You increase the number of spikes with the **Same contact area** !

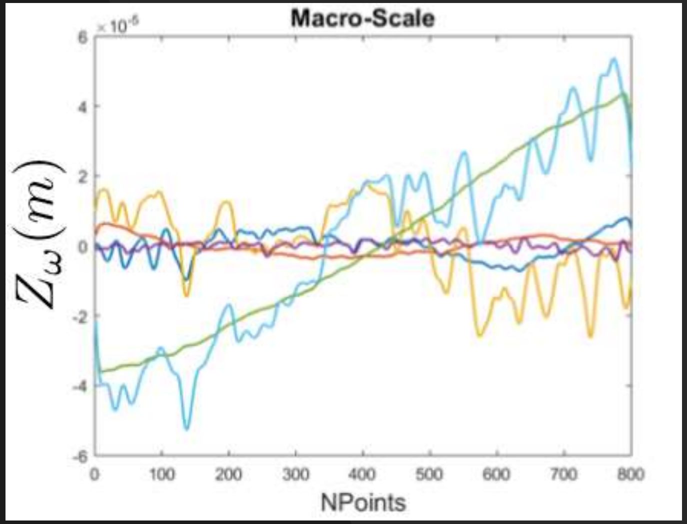
Higher is **Curvature** (spikes number) for the same area, higher is the thermal flux Q with a behaviour typical of percolation physics.

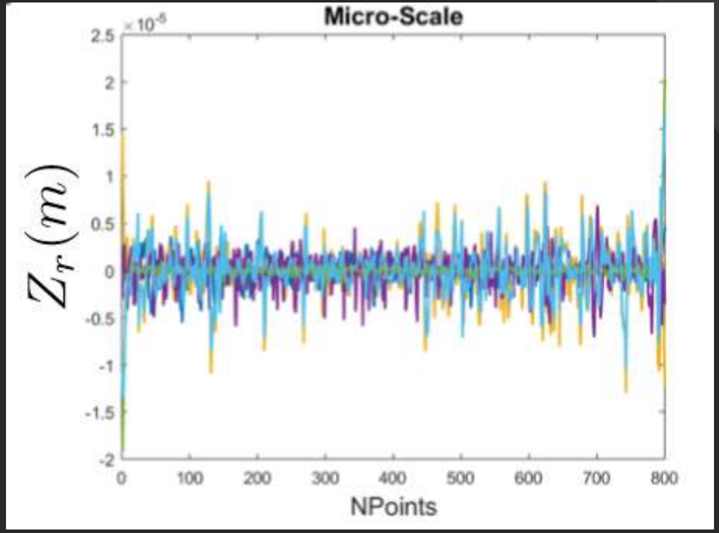


F.Chinesta et al., “High-resolution thermal analysis at thermoplastic pre-impregnated composite interfaces”, 2015, Composite Interfaces, 22/8, 767-777

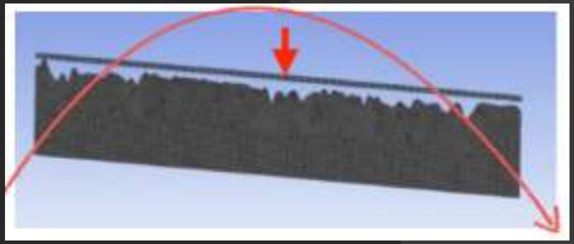
Heat & Momentum Transfers : Composites Consolidation



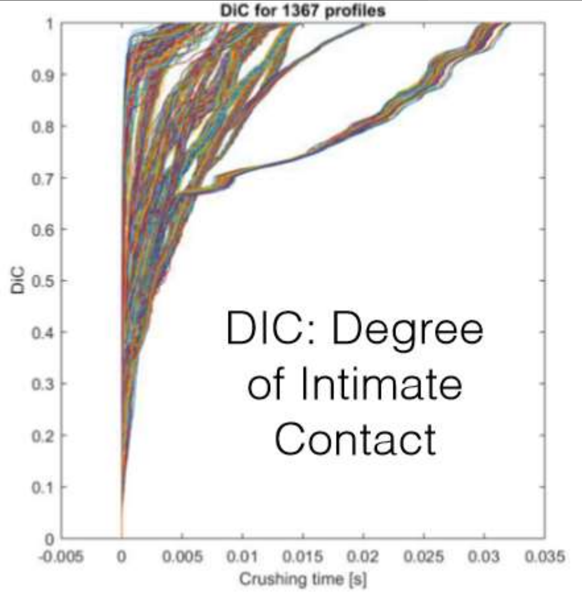




Heat & Momentum Transfers : Composites Consolidation



Huge Number of Crushing Experiments to Measure the Time Needed to Reach Intimate Contact Between Composite Sheets.



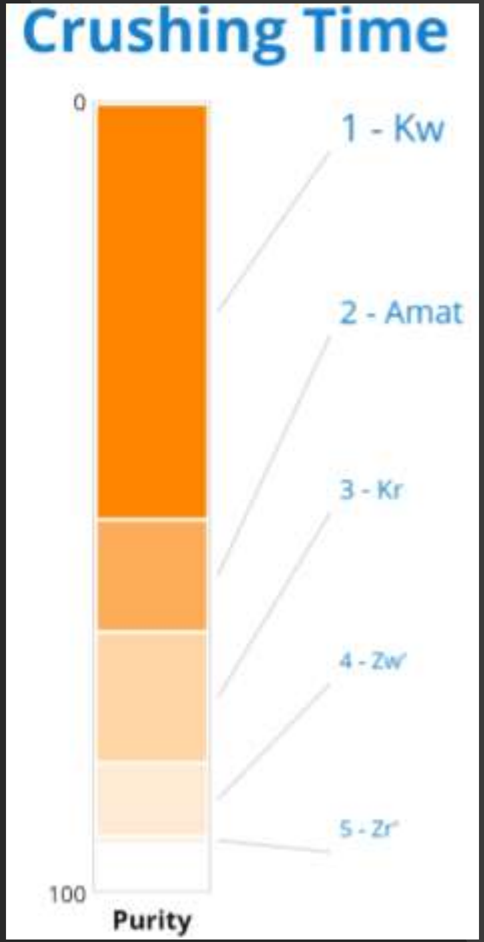
<u>**Five Variables Tested**</u> using ESI Software MINESET :

- Macroscopic Slope : First Derivative.
- Microscopic Slope : First Derivative.
- Macroscopic Curvature : Second Derivative.
- Microscopic Curvature : Second Derivative.
- Area.

<u>**For Crushing Time Determination**</u>

Heat & Momentum Transfers : Composites Consolidation

- **Curvature Appears to be The Key Parameter for Heat and Momentum Transfers.**
- In Real Surfaces with Complex (Multi-Scale) Roughness Distributions, Macro-Scale Curvature appeared (as intuitively expected) the Dominant Parameter.
- A Deep-Learning Model using Neural Networks was Created and Trained using Experimental Results. Results gave **<u>Curvature as the Dominant Parameter !</u>**



Heat & Momentum Transfers : Composites Consolidation

Huge Perspectives

- **Process Improvement** : Optimal design of surfaces for processing.
- **Surfaces Design** : adapted interfaces for particular properties.
- **New Processes** : 3D printing.
- **Optimal Process Control** : using curvature sensors.
- **Actives Surfaces** : adapting their geometry (curvature) to reach specific properties.

Conclusion

- Physics is governed by Curvature
- Curvature is a Major Parameter of all Physics Models.
- Thank You