



**The Abdus Salam
International Centre for Theoretical Physics**



2240-26

**Advanced School on Scaling Laws in Geophysics: Mechanical and
Thermal Processes in Geodynamics**

23 May - 3 June, 2011

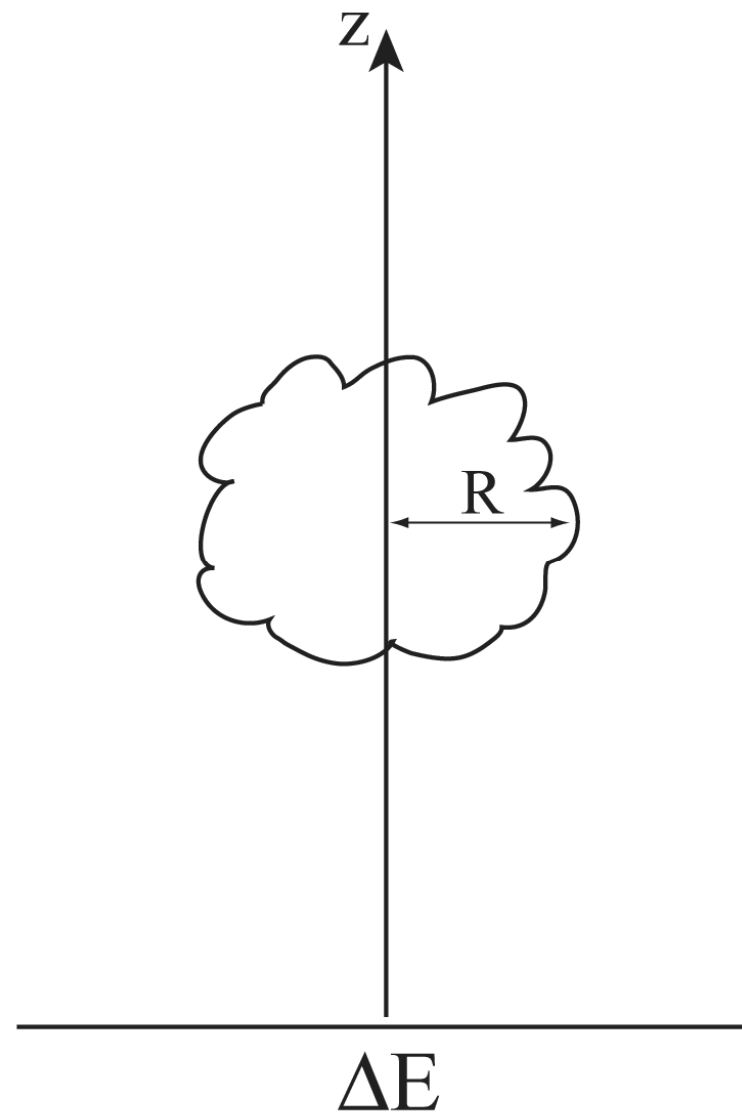
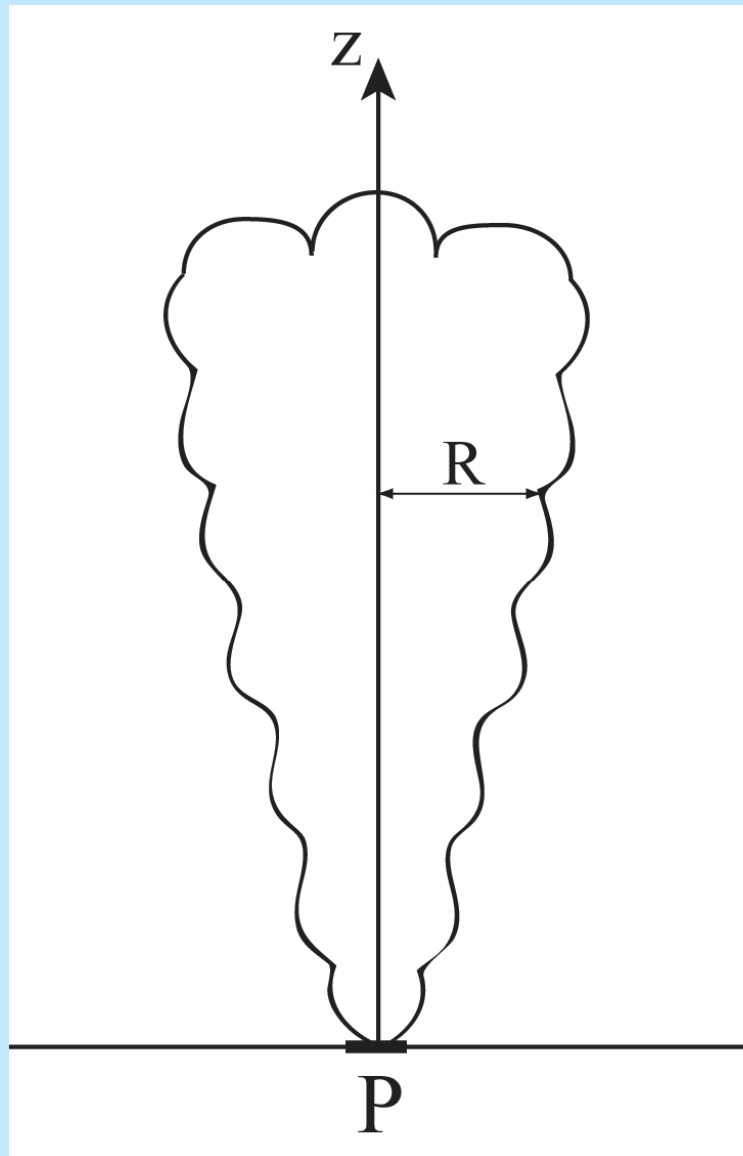
Convection - Part I

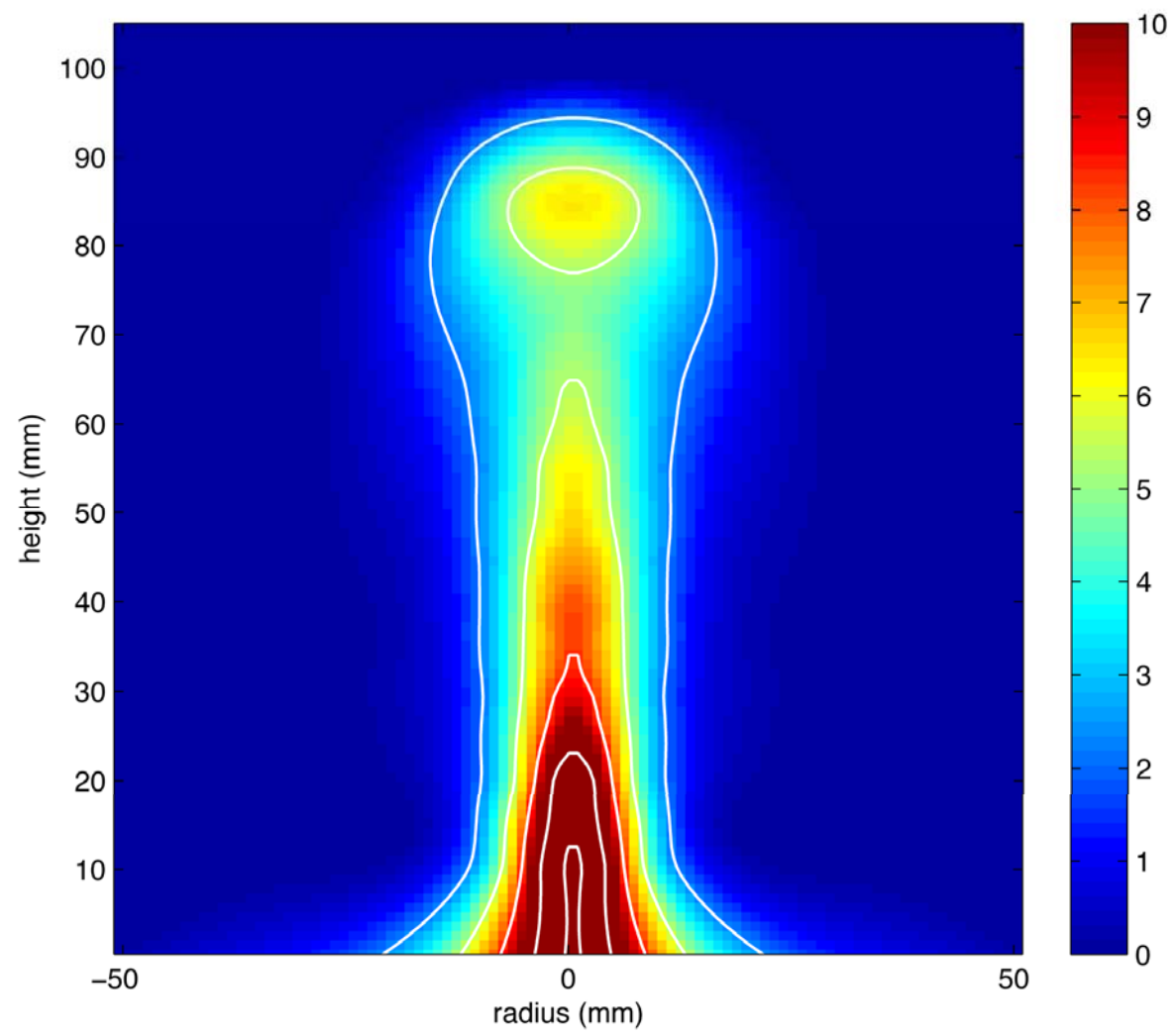
Claude JAUPART
*Institut de Physique du Globe de Paris
France*

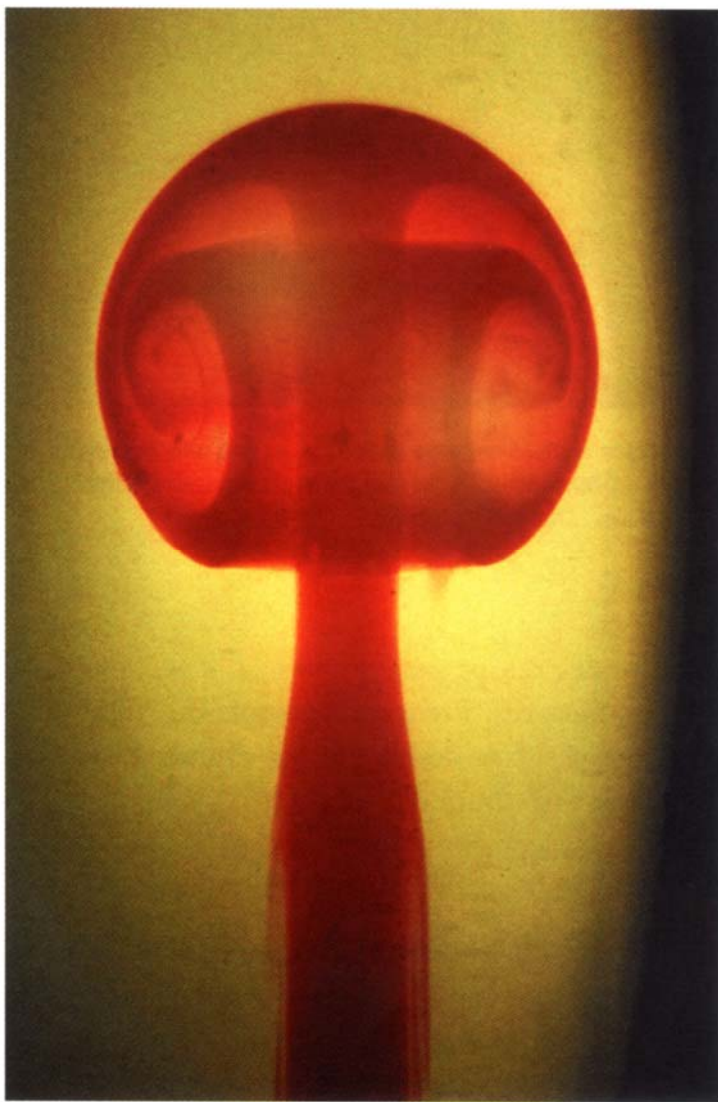
CONVECTION

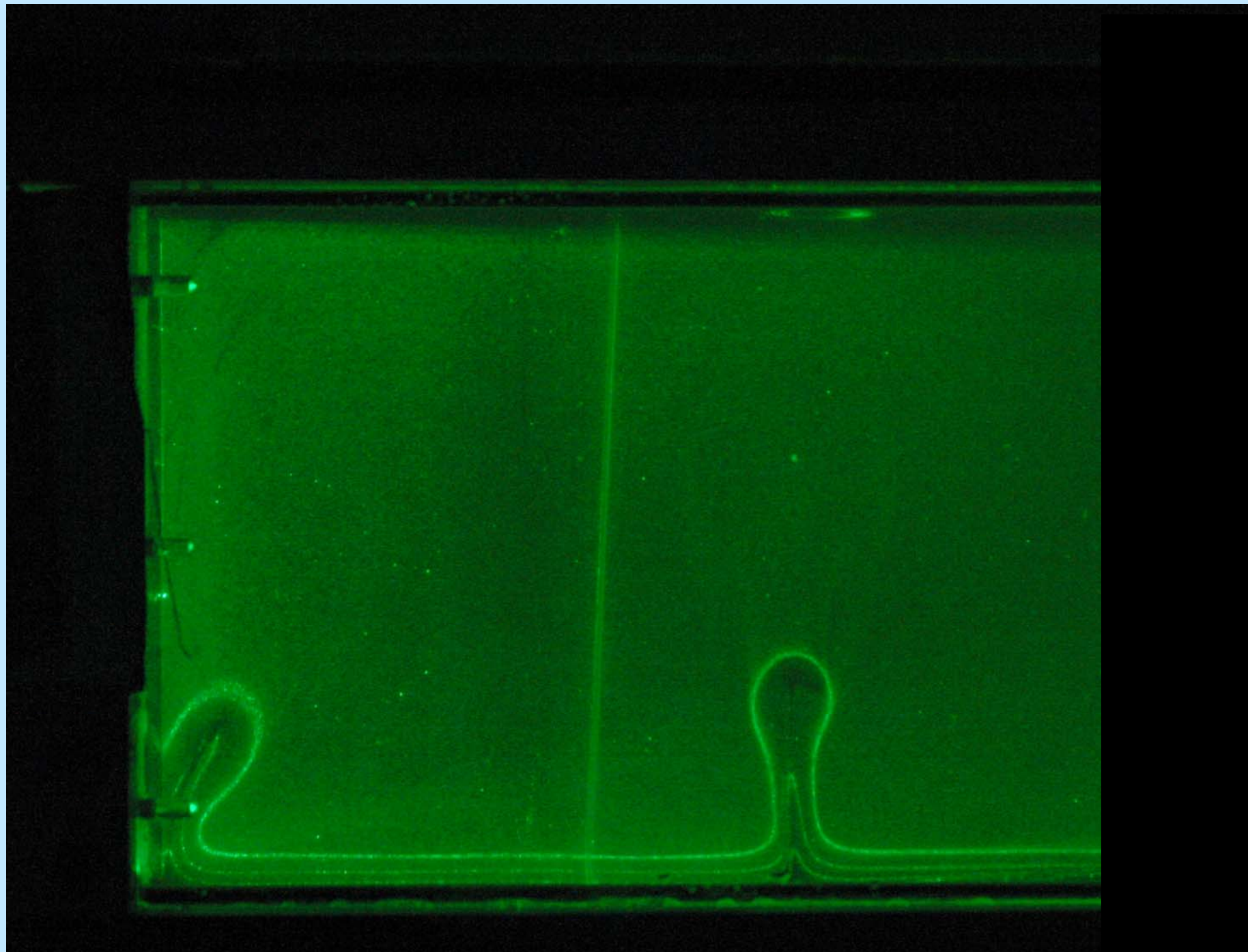
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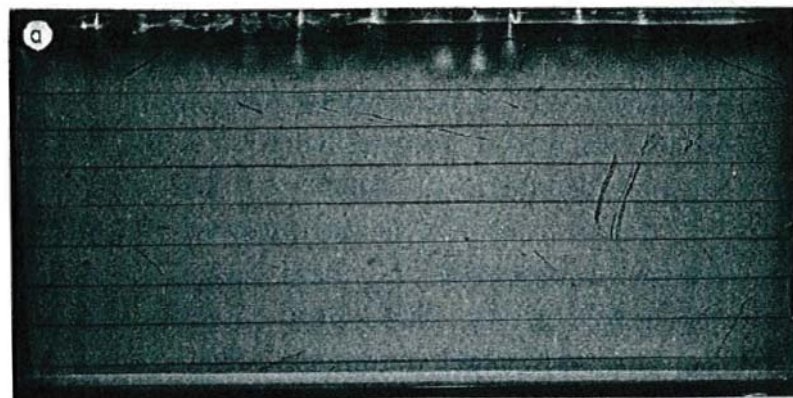


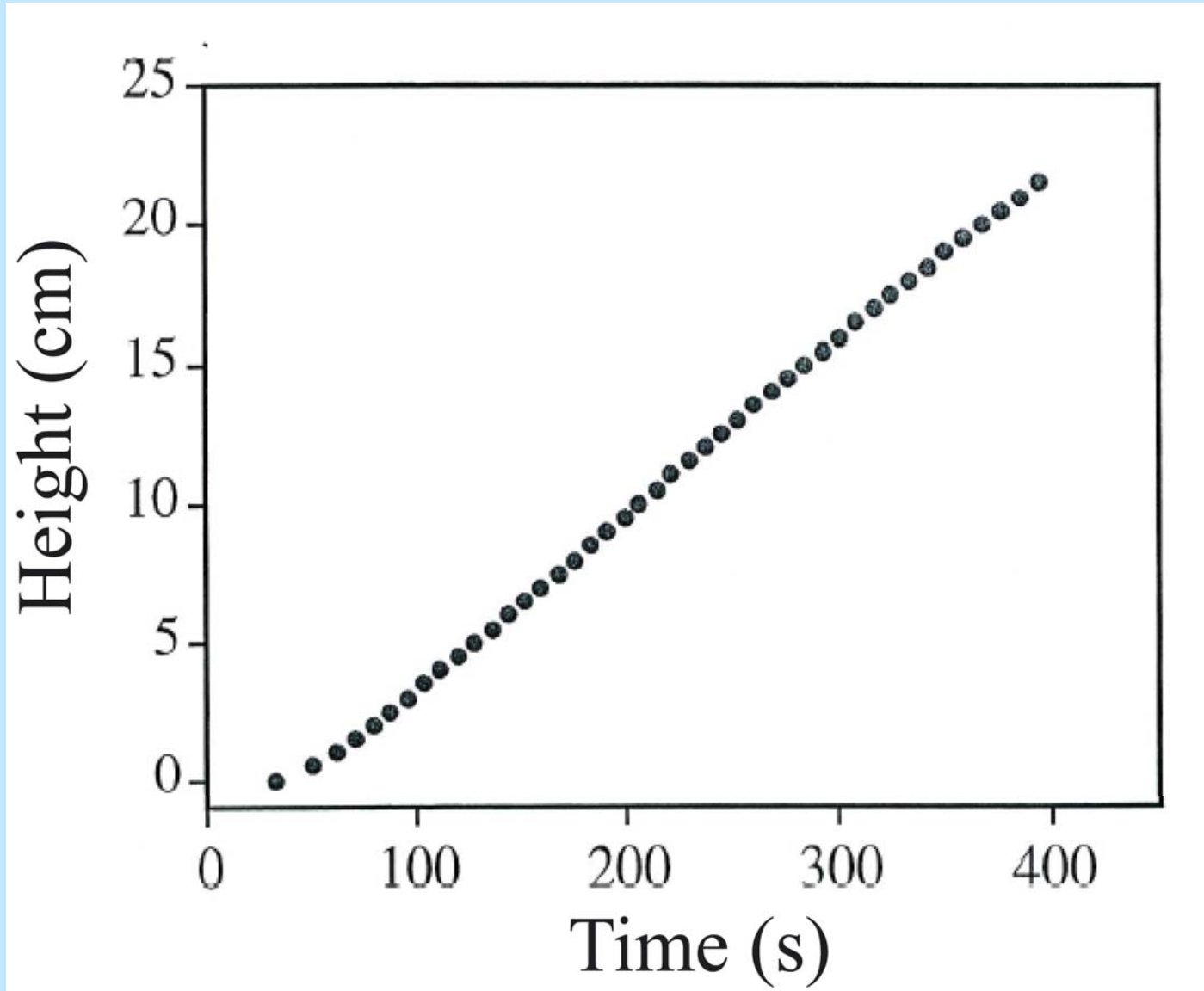


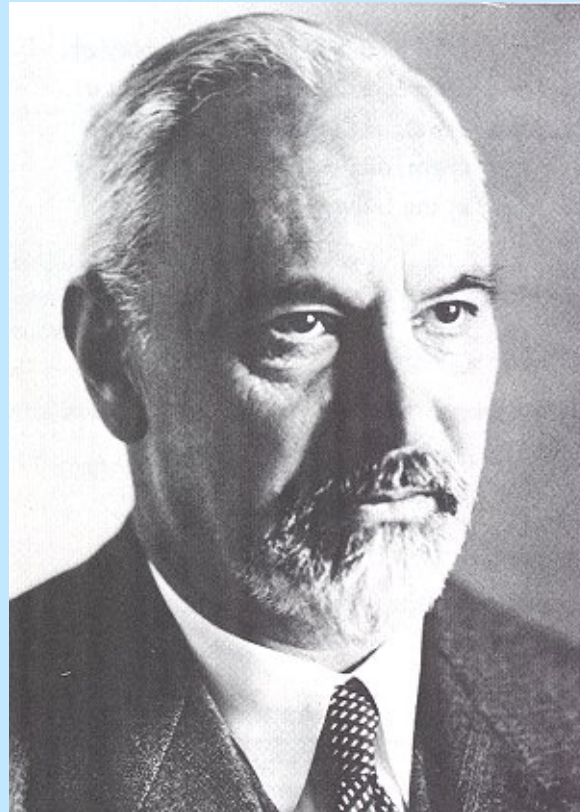




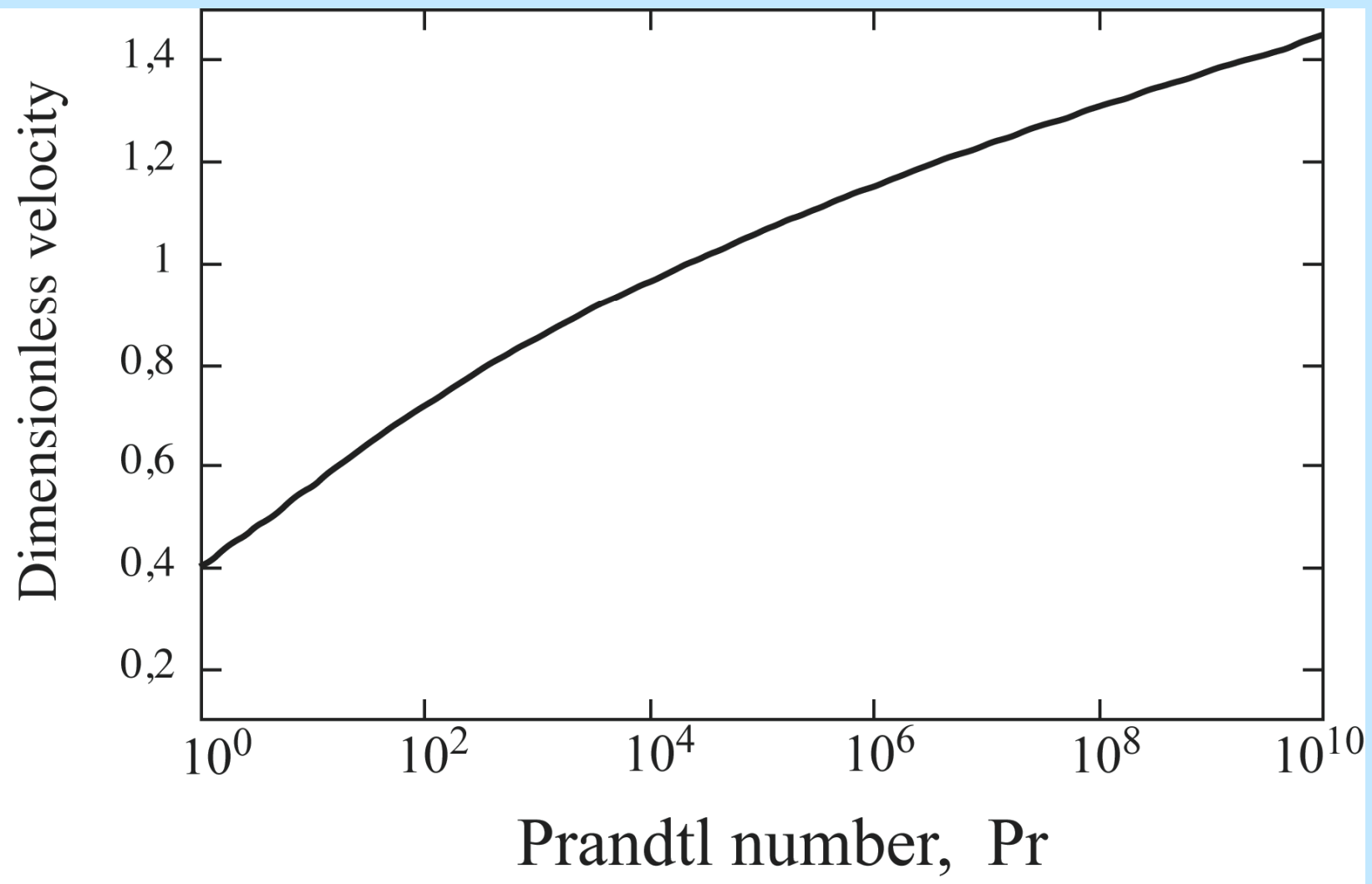


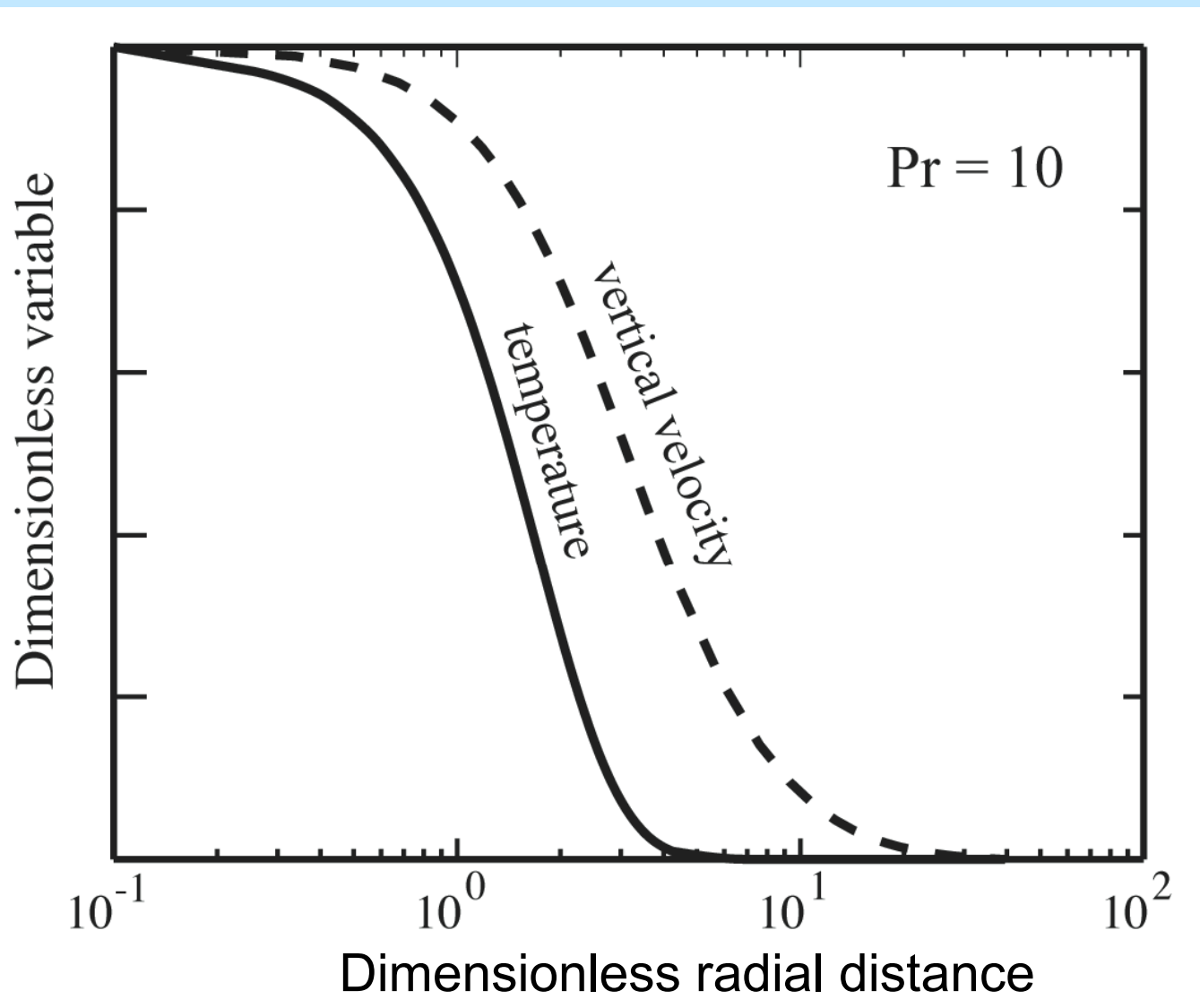


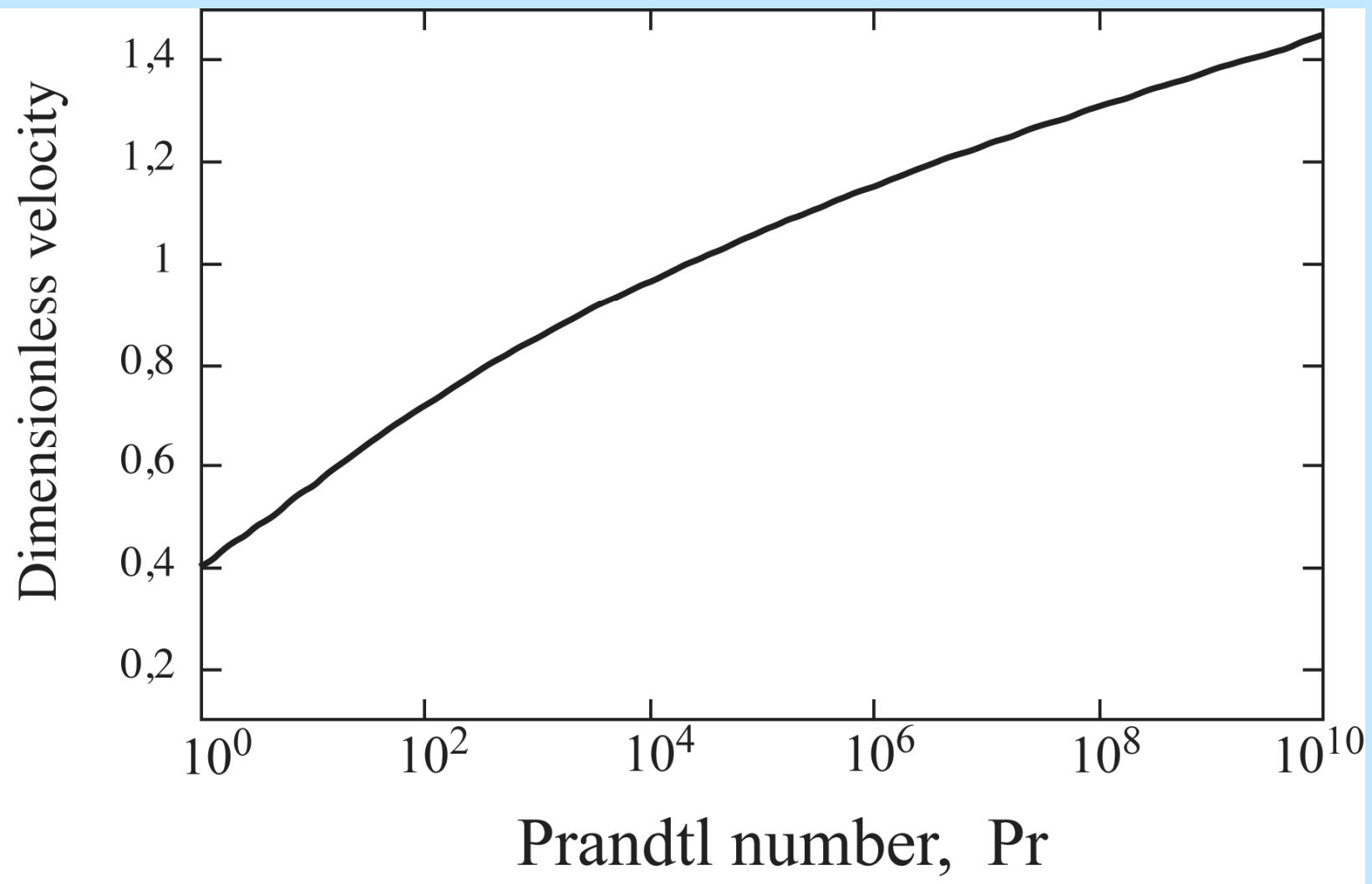


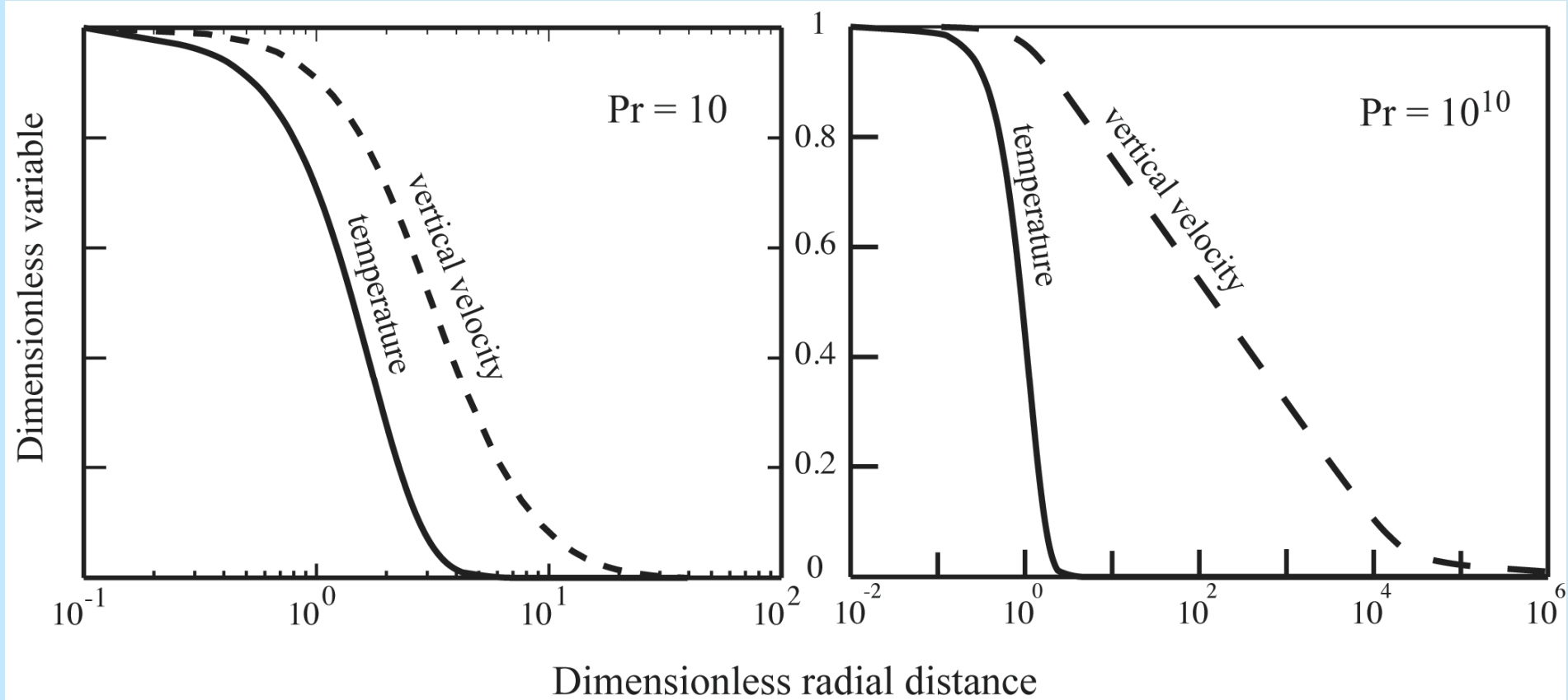


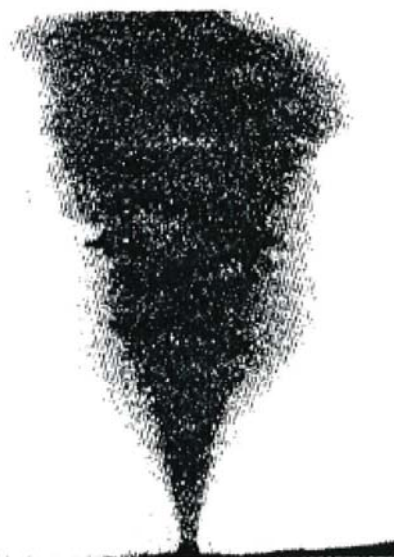
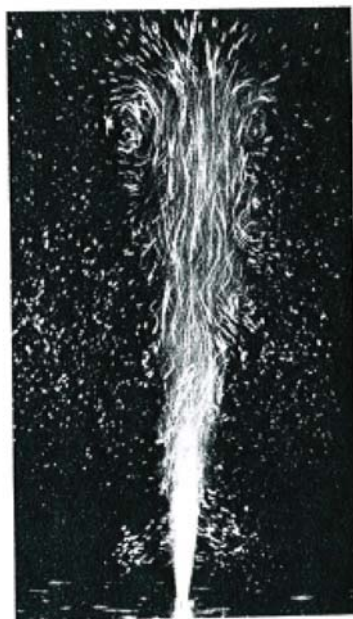
L. Prandtl
1875-1953

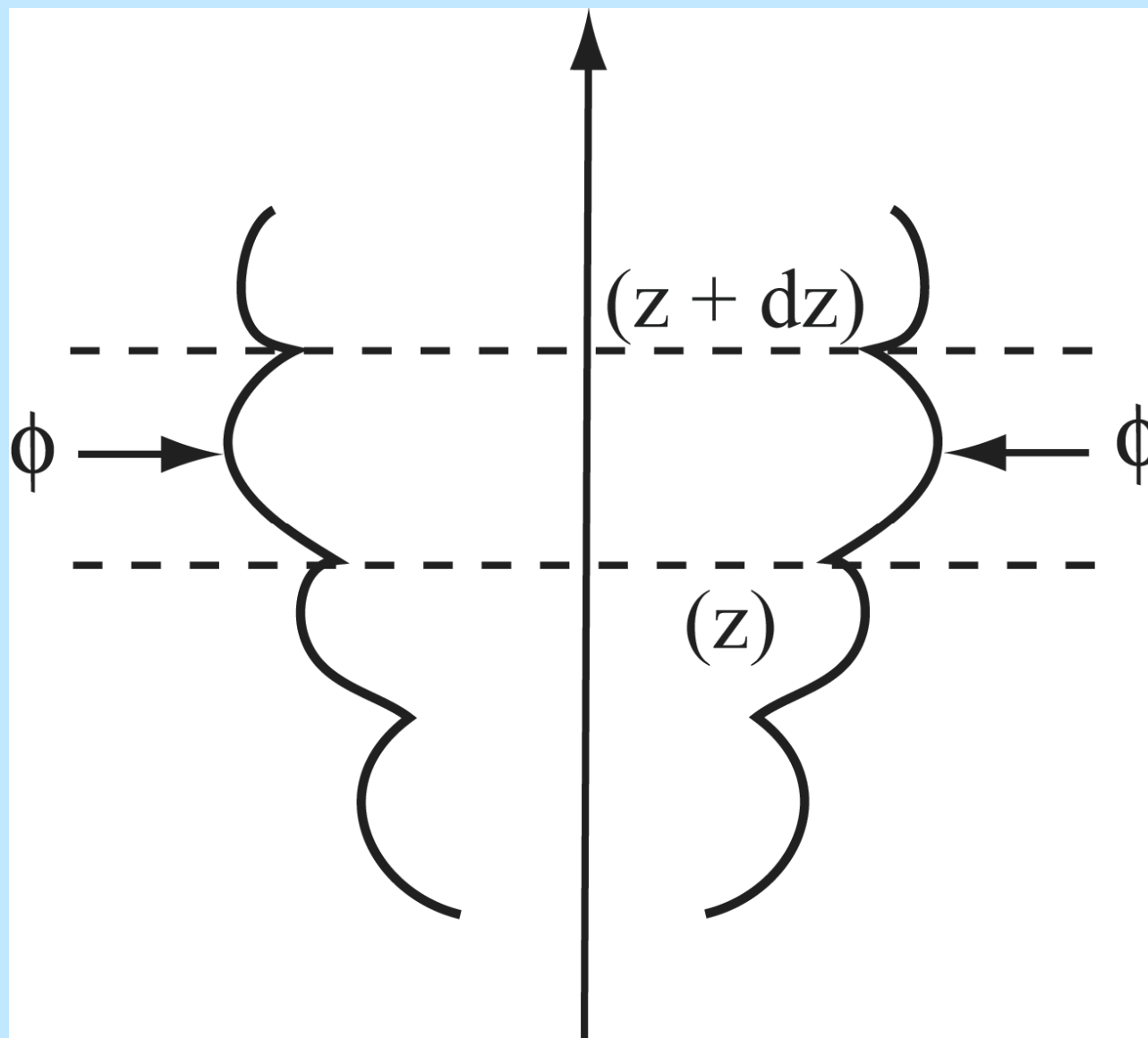








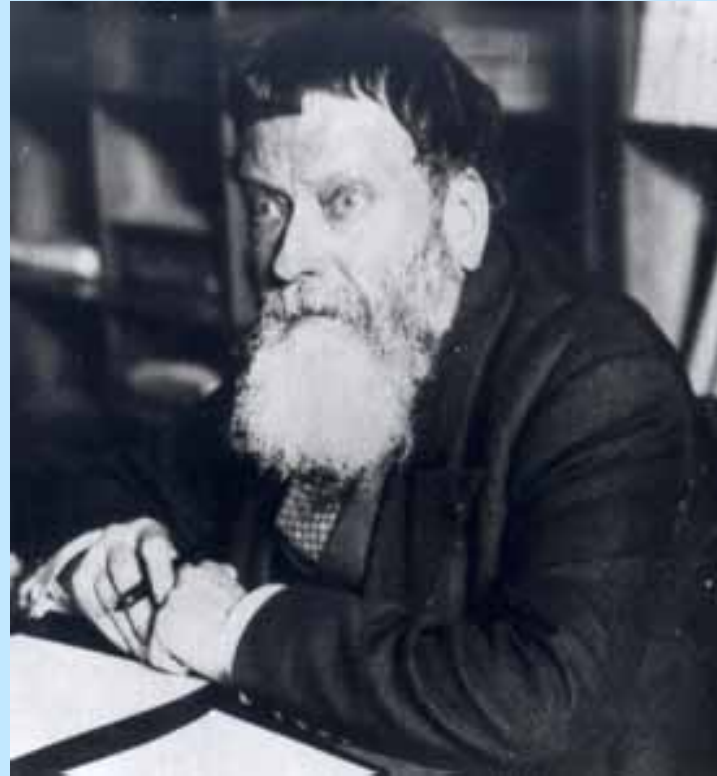




Rayleigh-Benard Convection



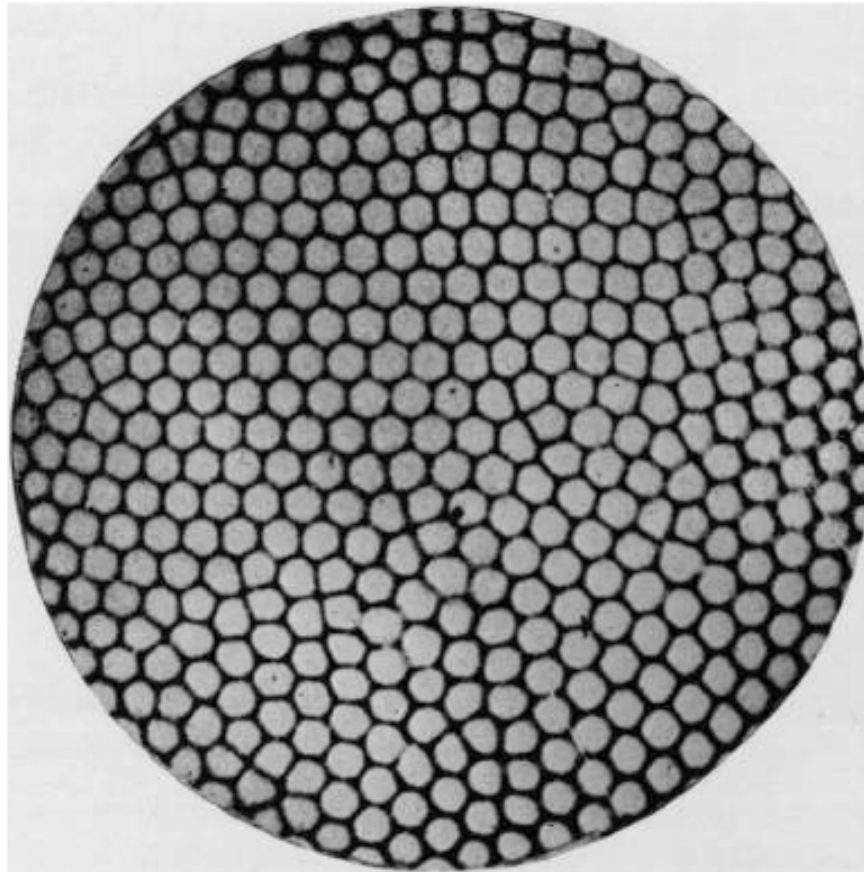
Lord Rayleigh 1842 - 1919



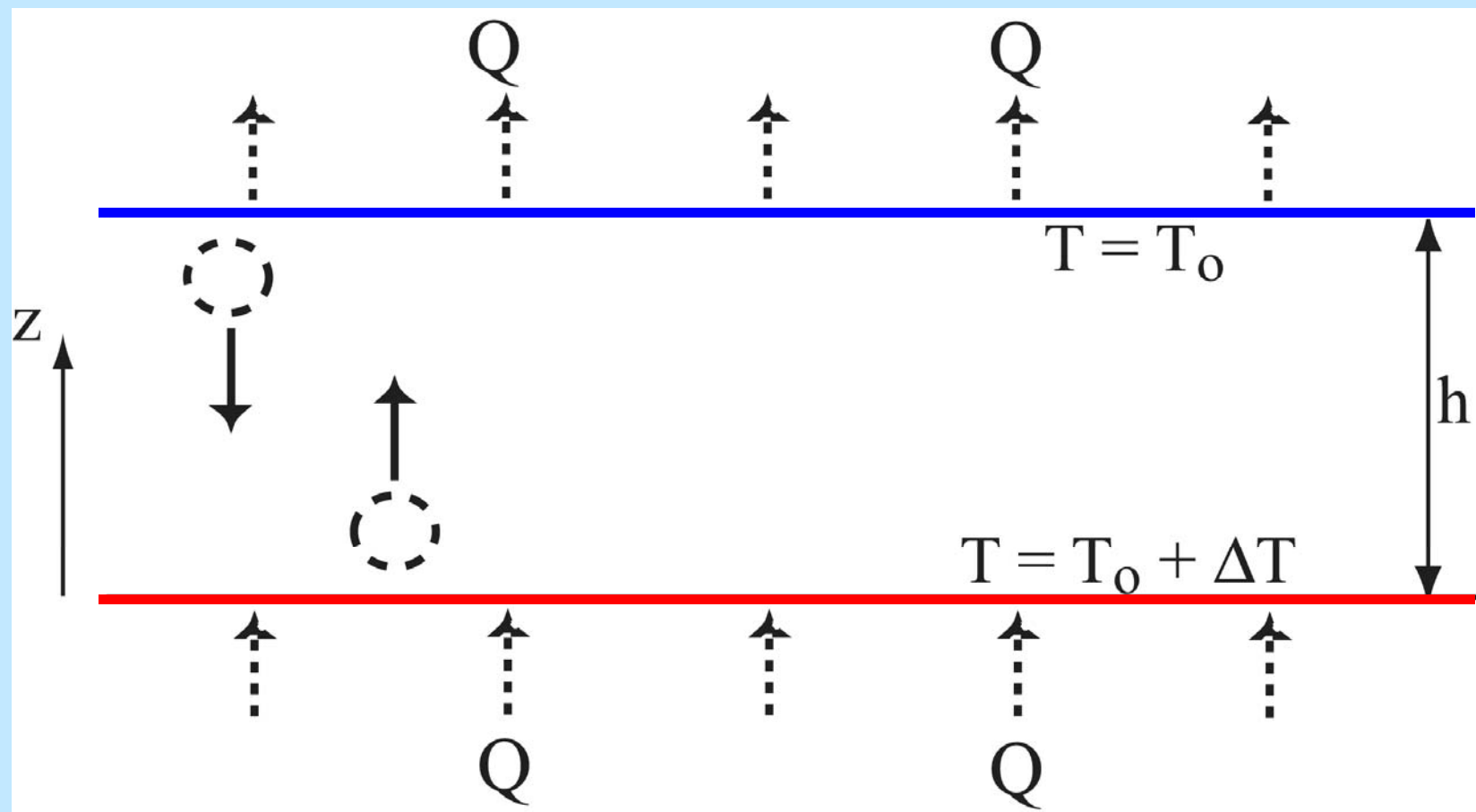
Henri Bénard 1874-1939

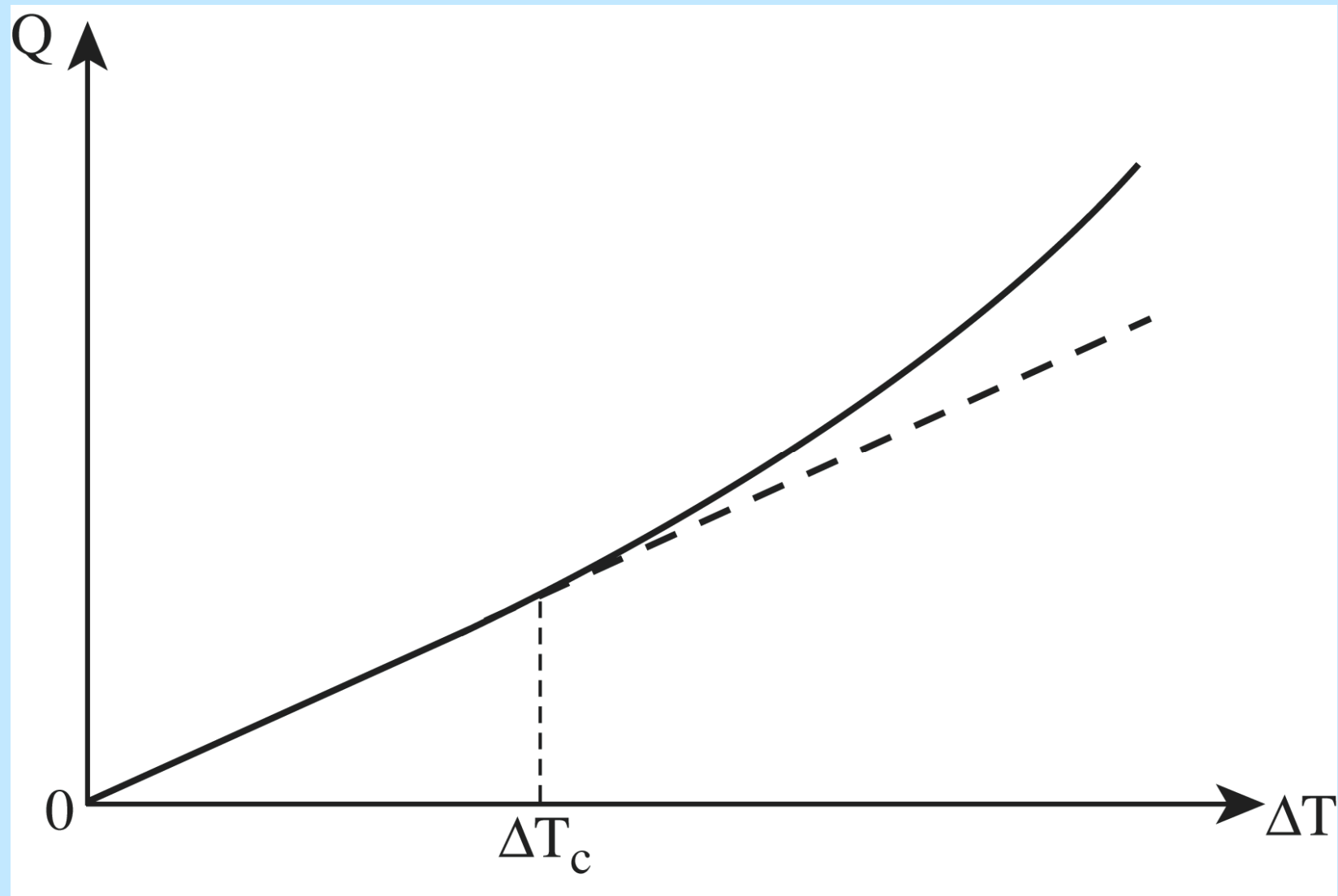
Les Tourbillons Cellulaires dans une Nappe Liquide

Henri Benard



Revue generale des Sciences XII, 1261 (1900)

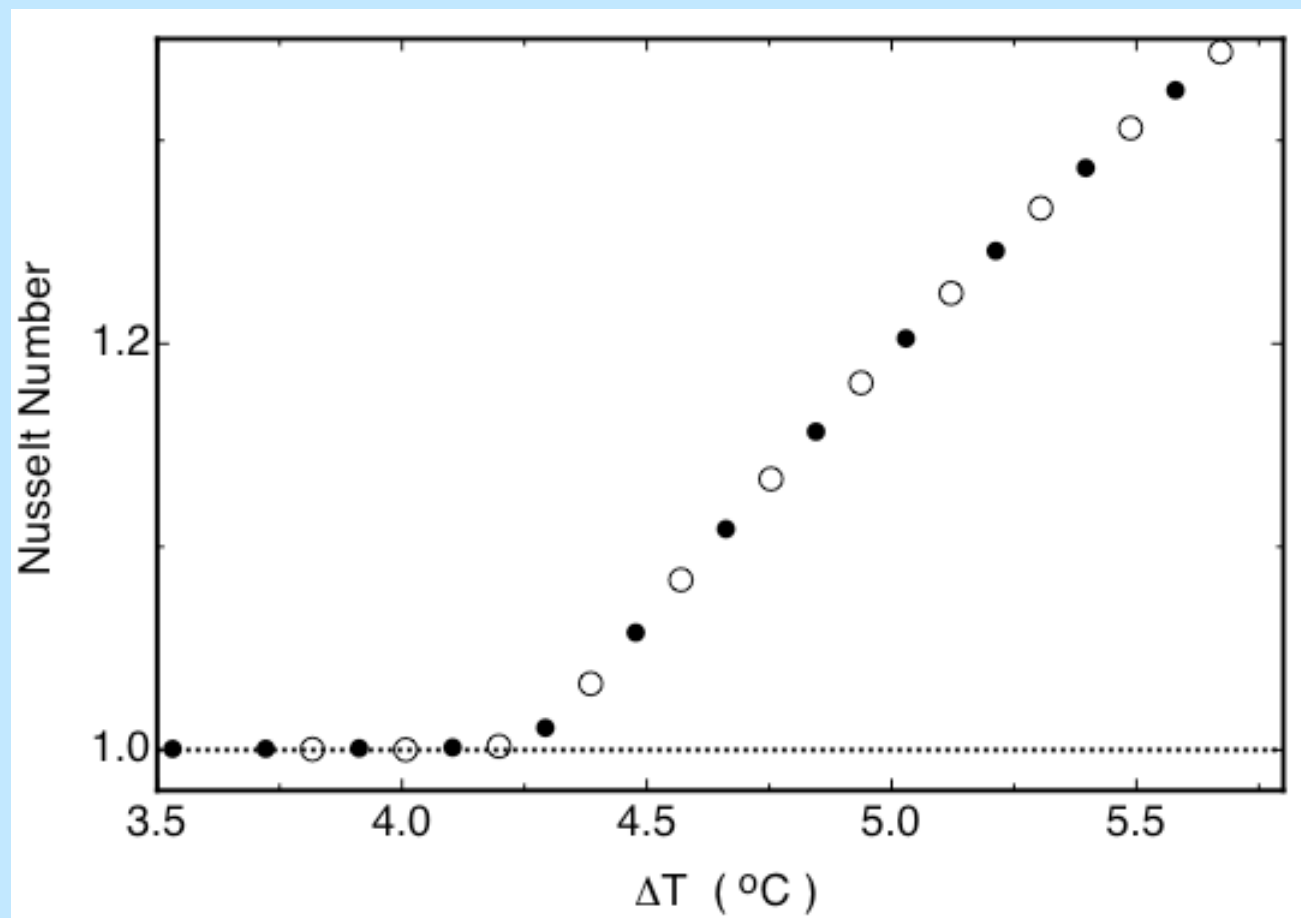






William Nusselt (1882-1957)

W. Nusselt, Forsch.-Arbeit auf dem Gebiete des Ing. Wesens, Heft **63,64** (1907);
Gesundh.-Ing. **42,43**, 477 (1915).



Scales

Length h

Velocity W

Time $\frac{h}{W}$

Pressure $\frac{\mu W}{h}$

Scales

Length h

Velocity W

Time $\frac{h}{W}$

Pressure $\frac{\mu W}{h}$

$$W = \frac{\rho_o g \alpha \Delta T h^2}{\mu}.$$

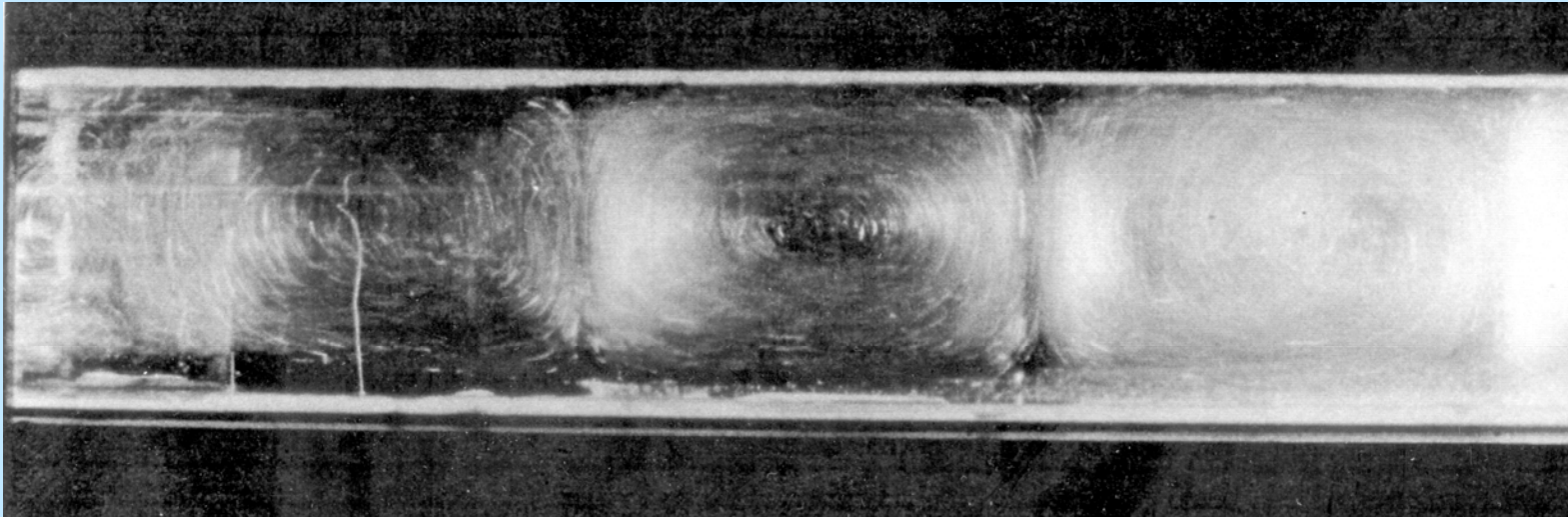
Dimensionless equations for thermal convection

$$\nabla \cdot \mathbf{v} = 0$$

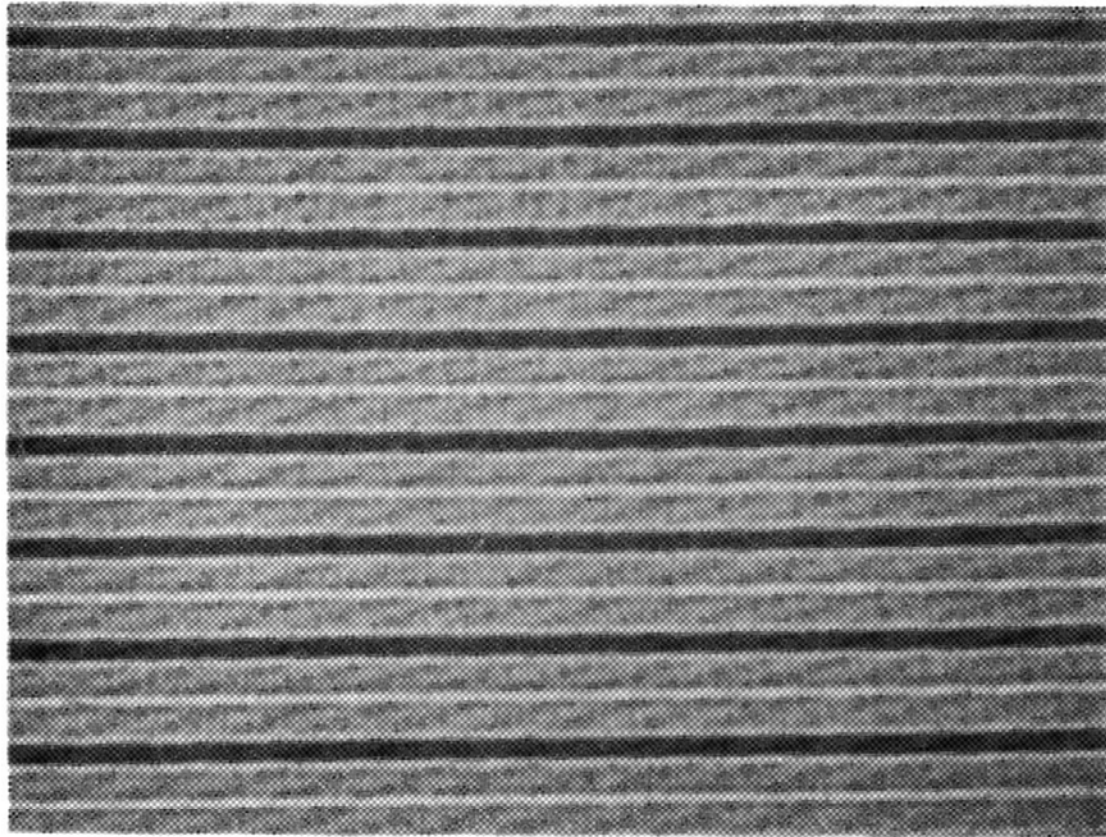
$$\text{RaPr}^{-1} \left[\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} \right] = -\nabla P + \nabla^2 \mathbf{v} + T \mathbf{n}_z$$

$$\text{Ra} \left[\frac{\partial T}{\partial t} + \mathbf{v} \cdot \nabla T \right] = \nabla^2 T + \frac{\rho H h^2}{\lambda \Delta T}$$

Seen from the side

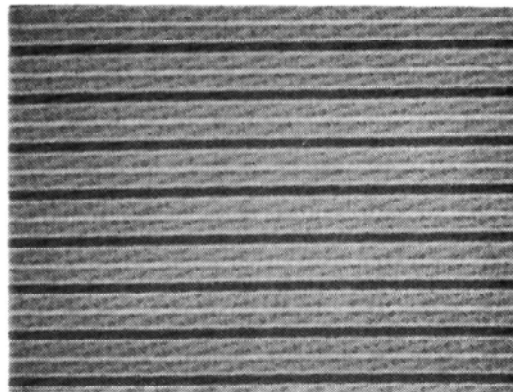
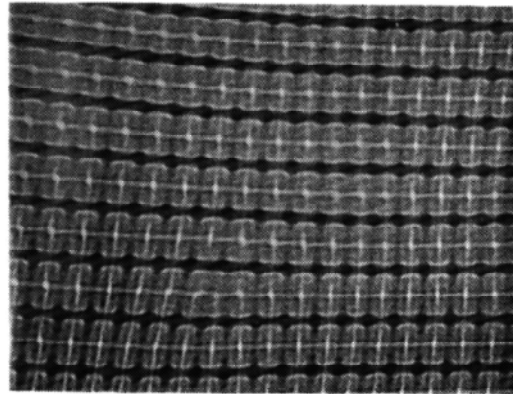
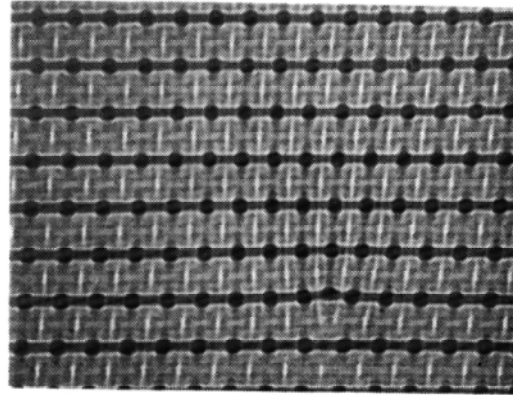


Seen from above

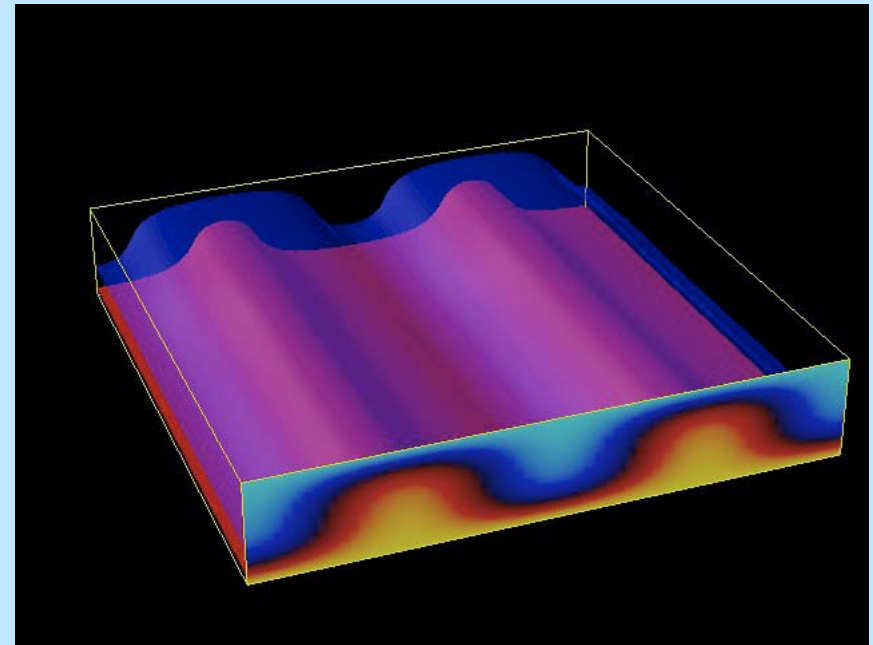
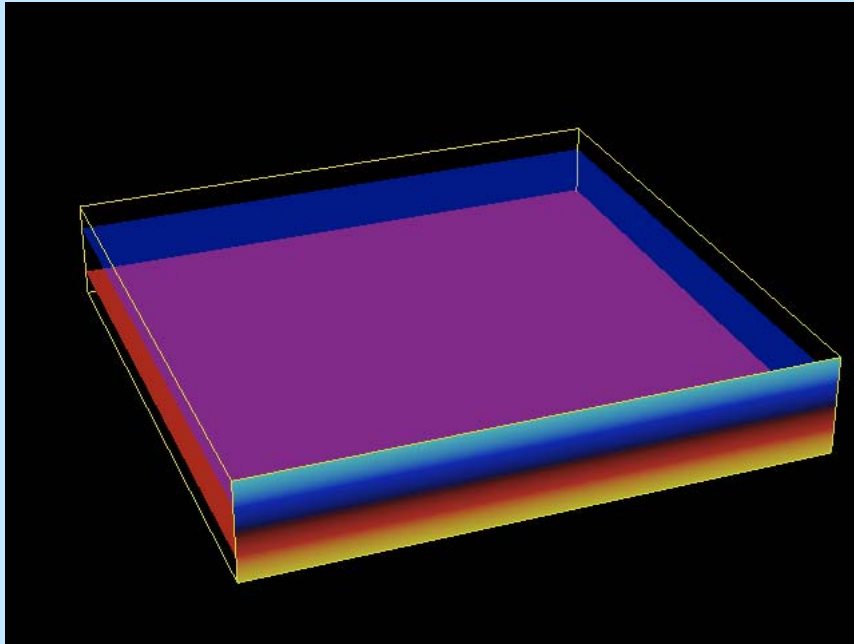


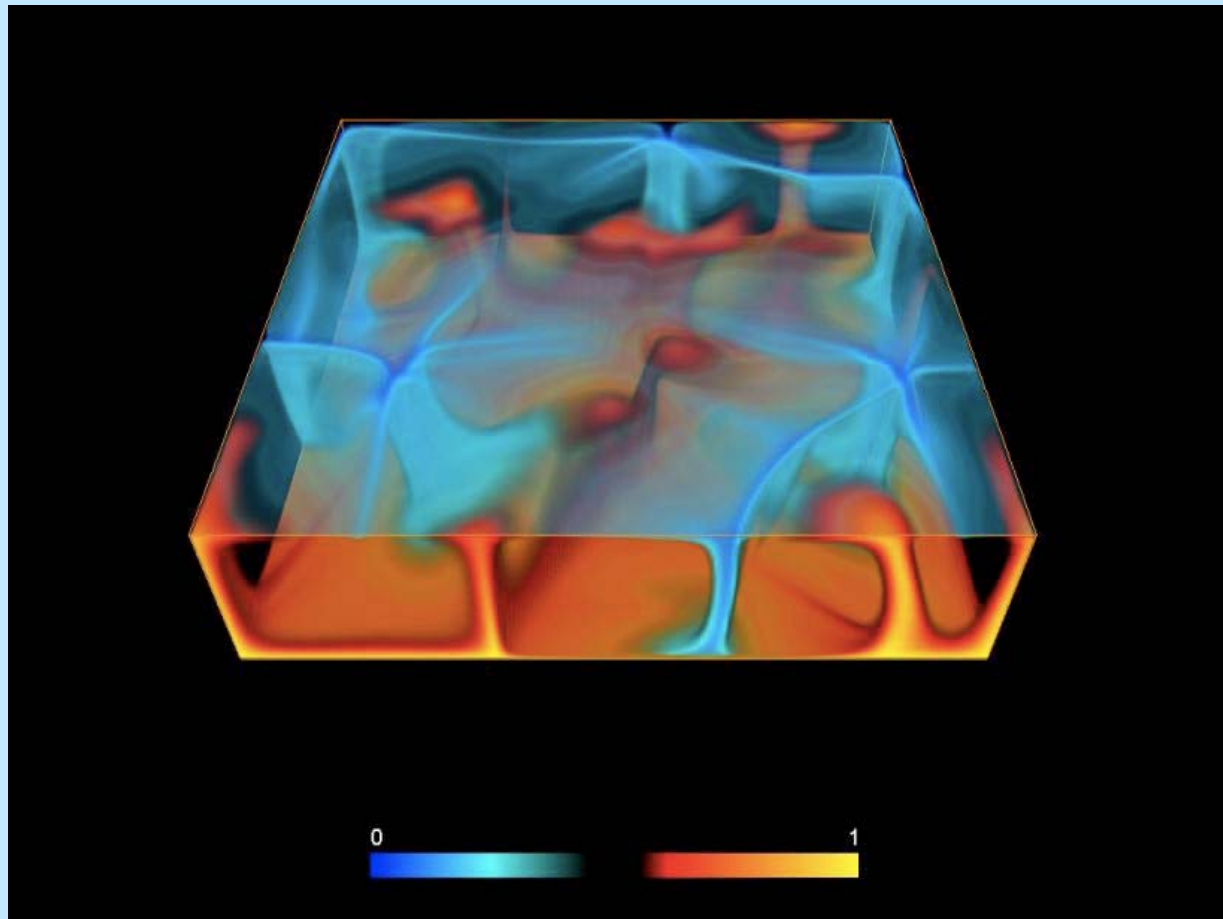
$$\approx 10^3 < Ra < \approx 10^4$$

Ra

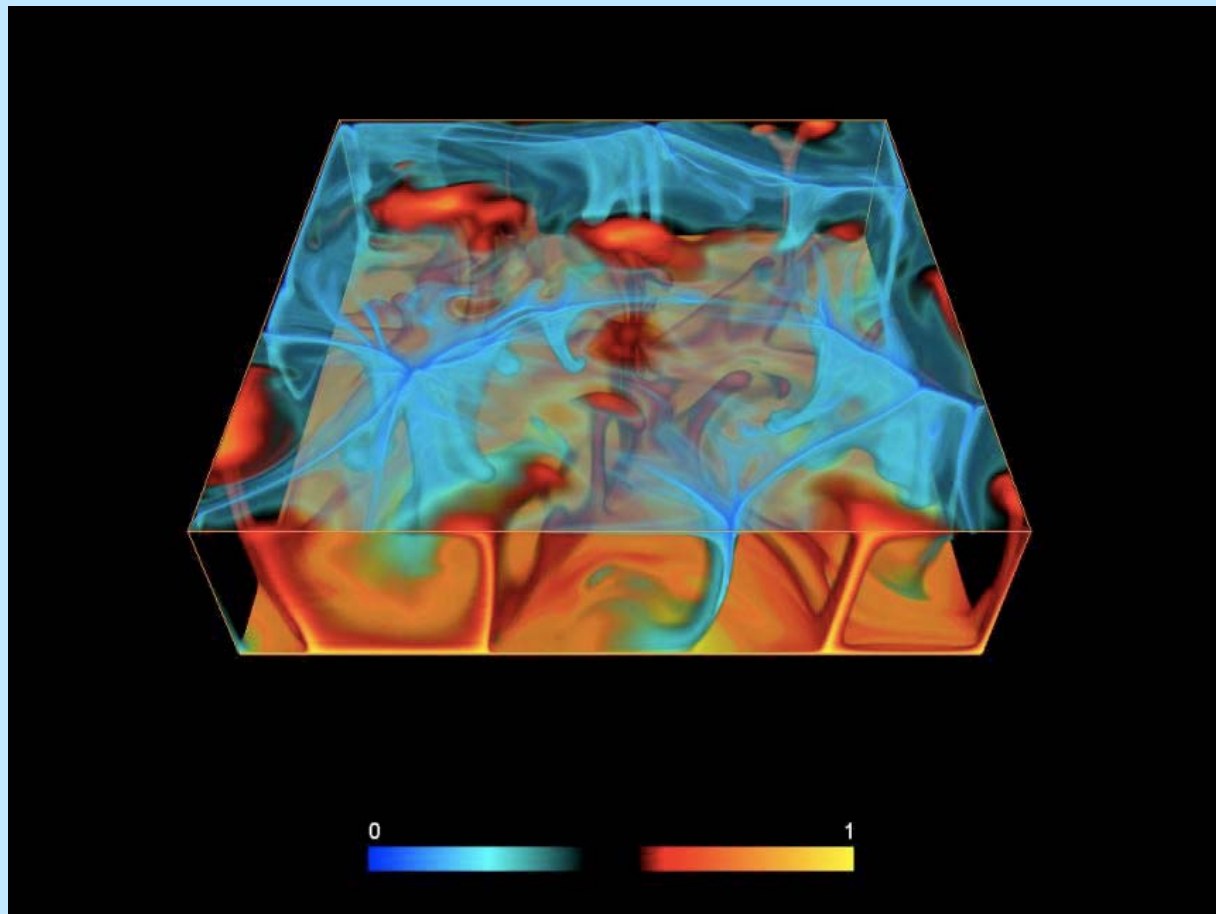


$Ra \approx 10^4$

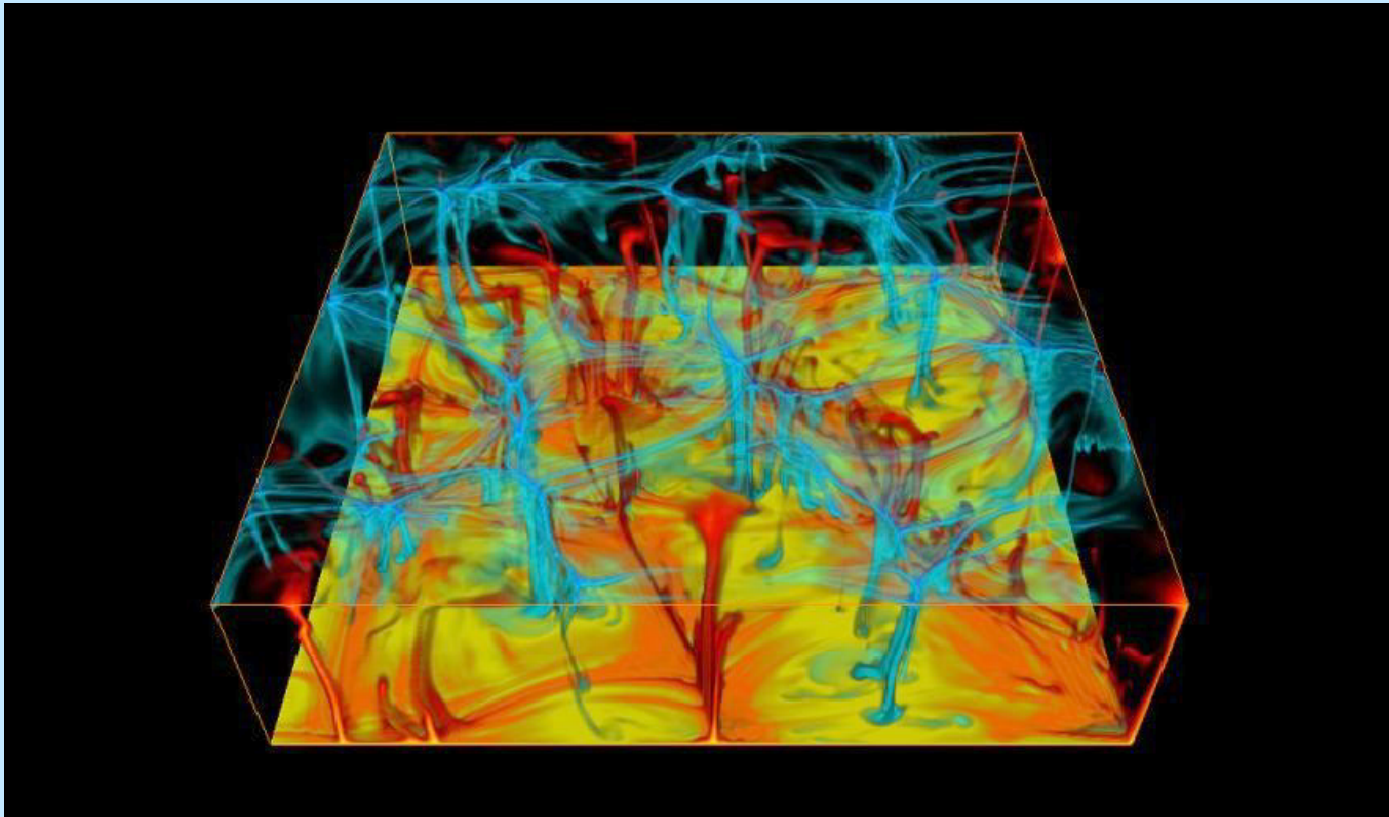




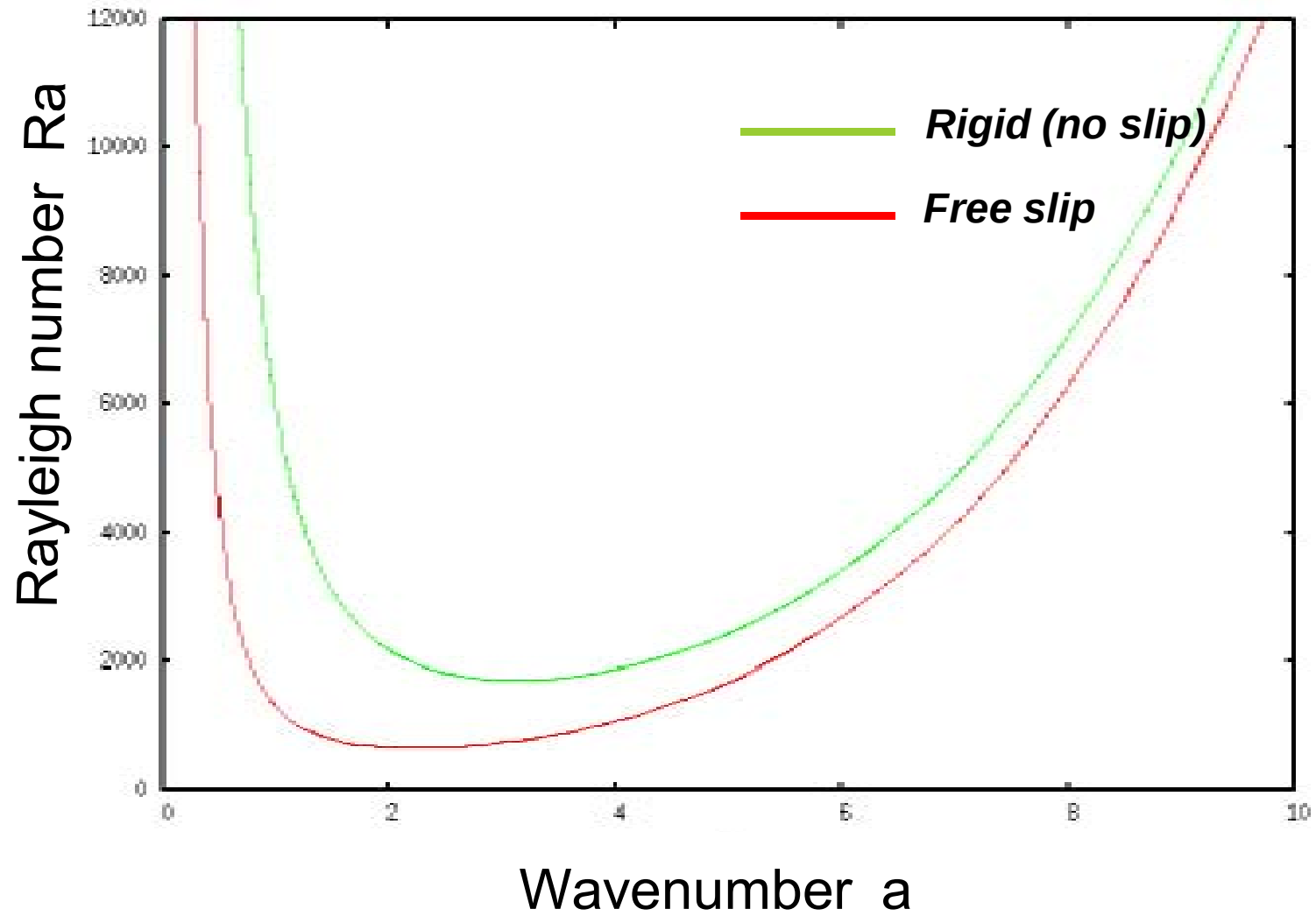
$$Ra = 10^6$$

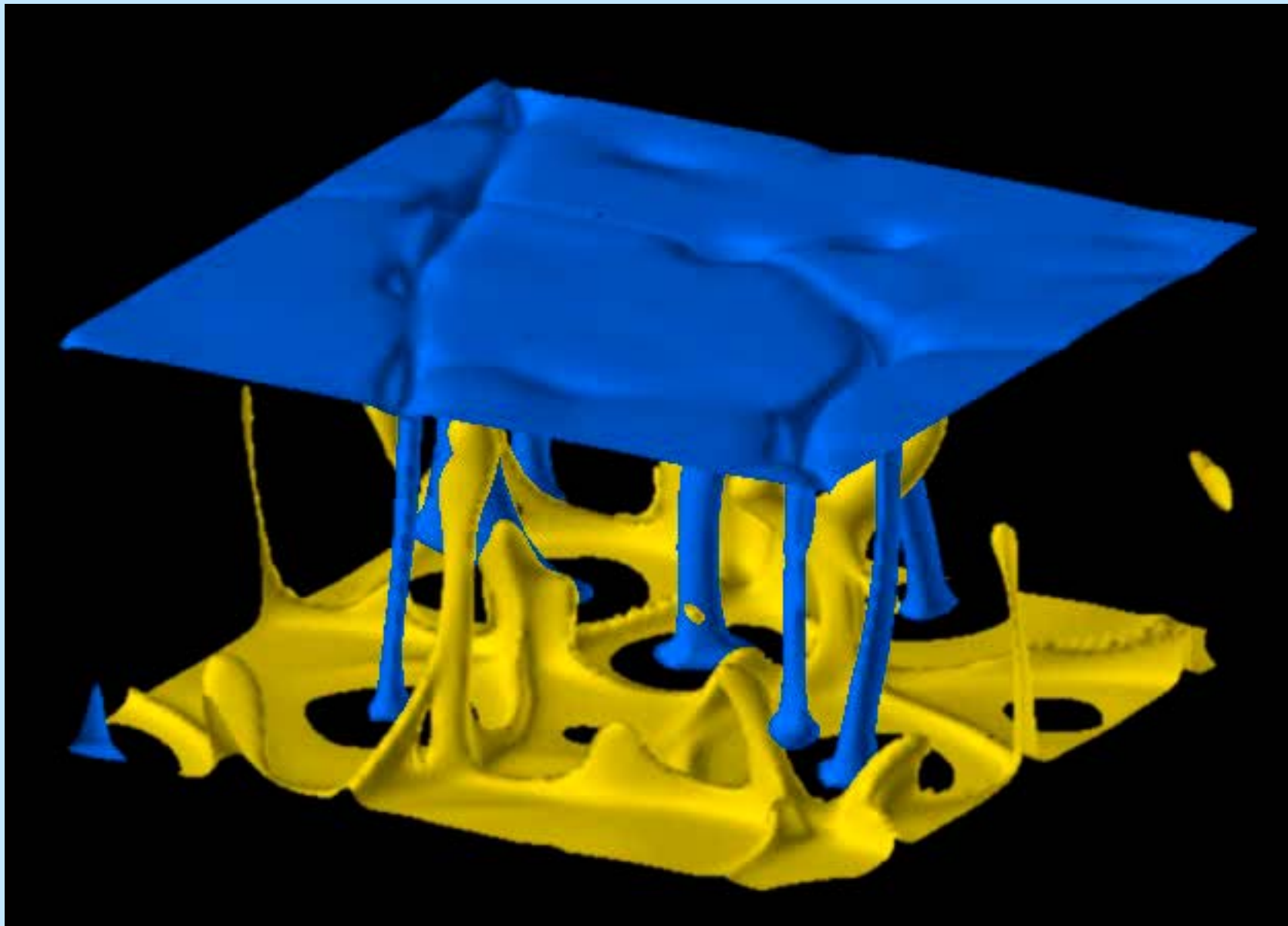


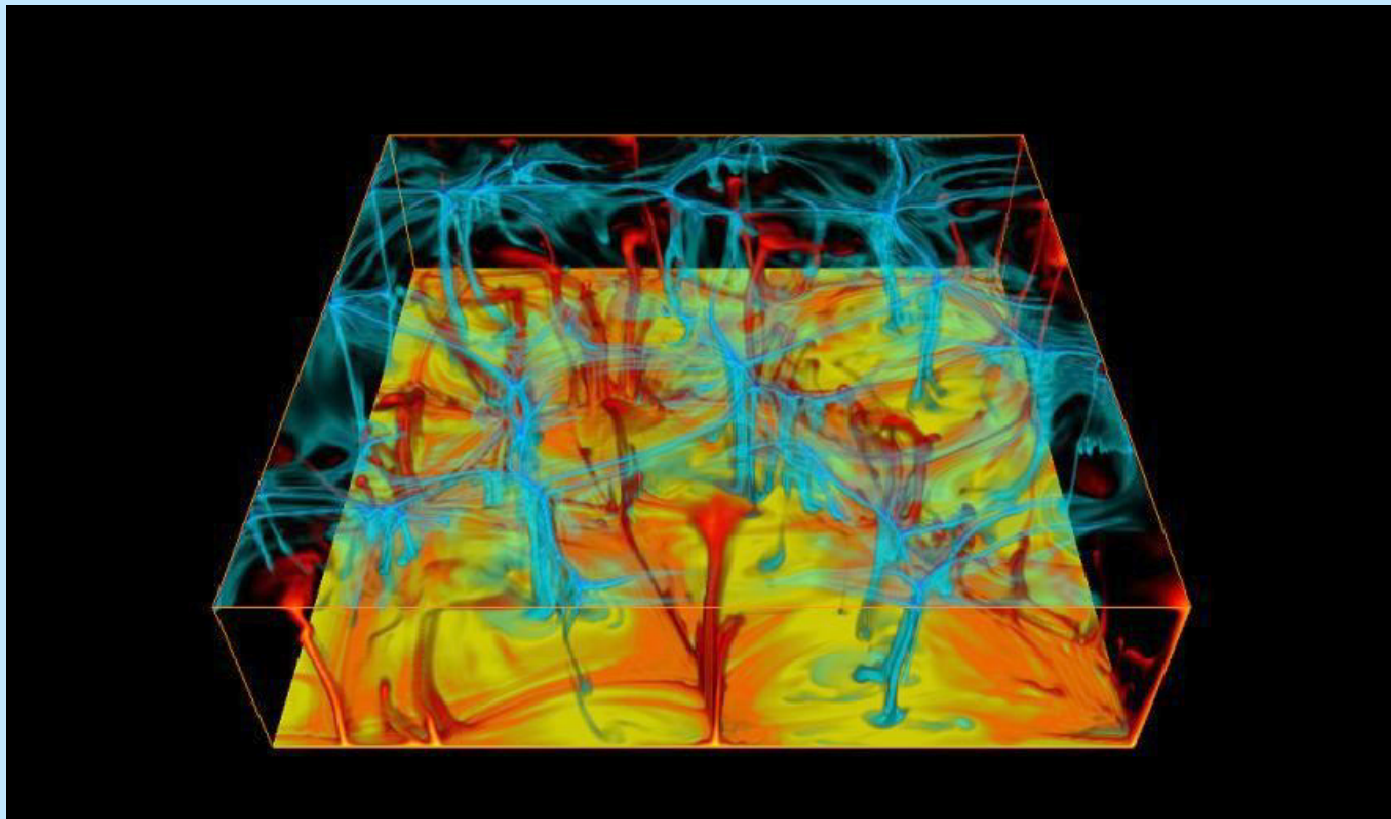
$$\text{Ra} = 10^7$$



$$Ra = 10^8$$







$$\text{Ra} = 10^8$$

