Active dumbbells: from diffusion properties to aggregation phenomena

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Bari, 11 December, 2015

A collective effort

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  - Davide Marenduzzo
- OXFORD
  - Giuseppe Laghezza
- PARIS
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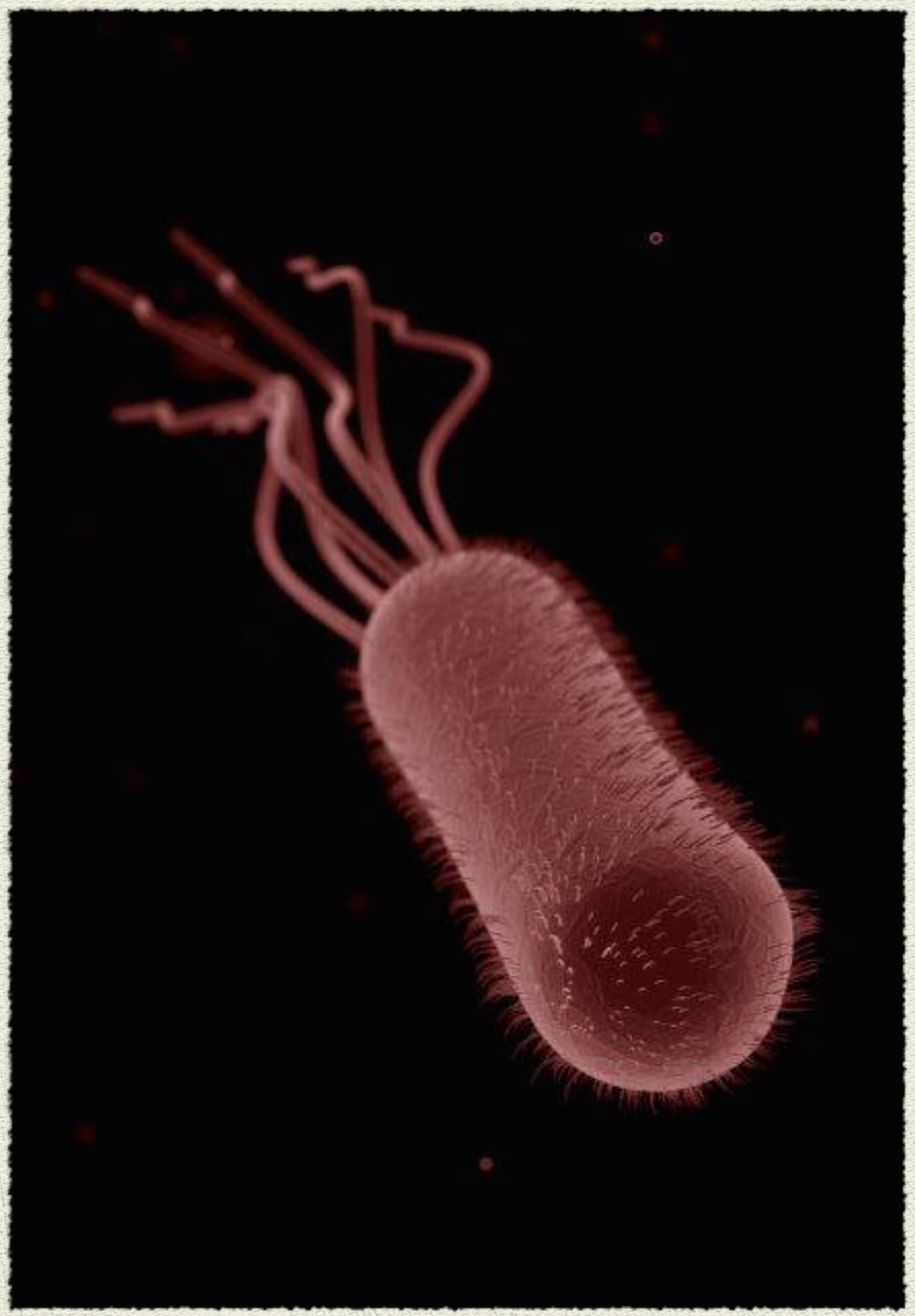
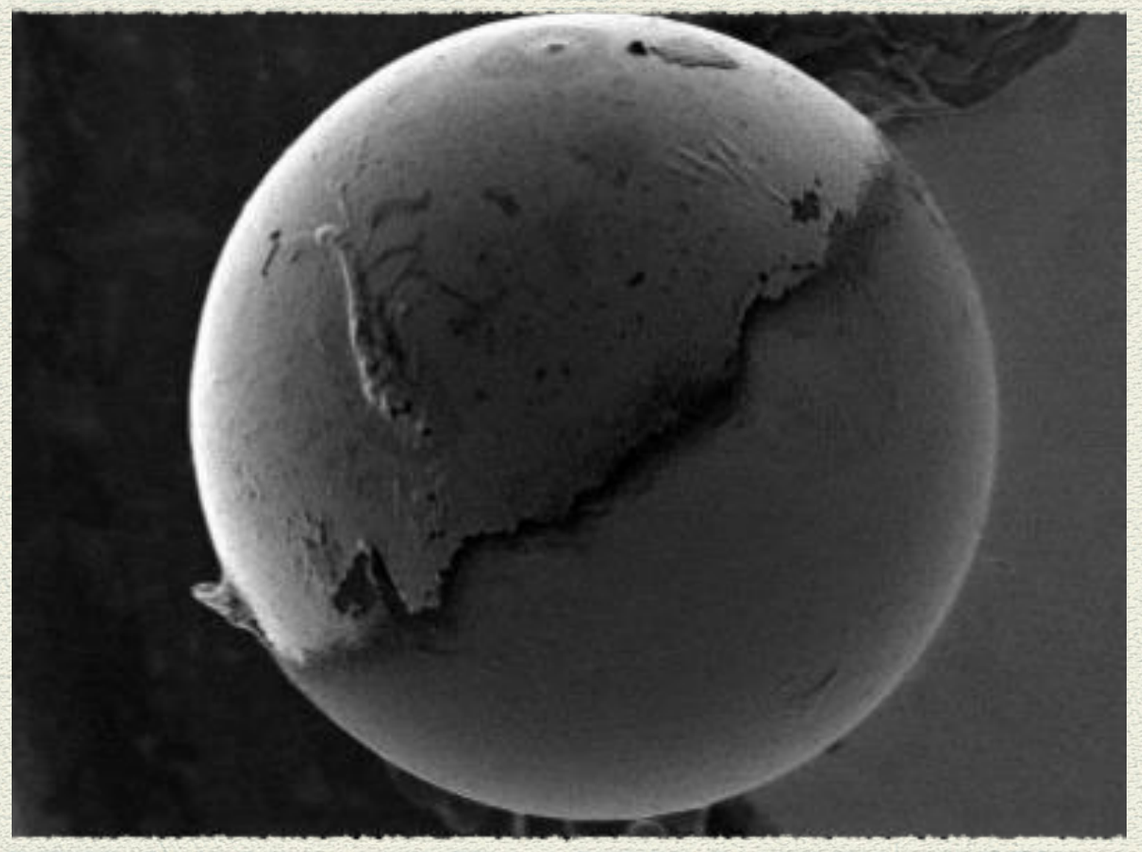
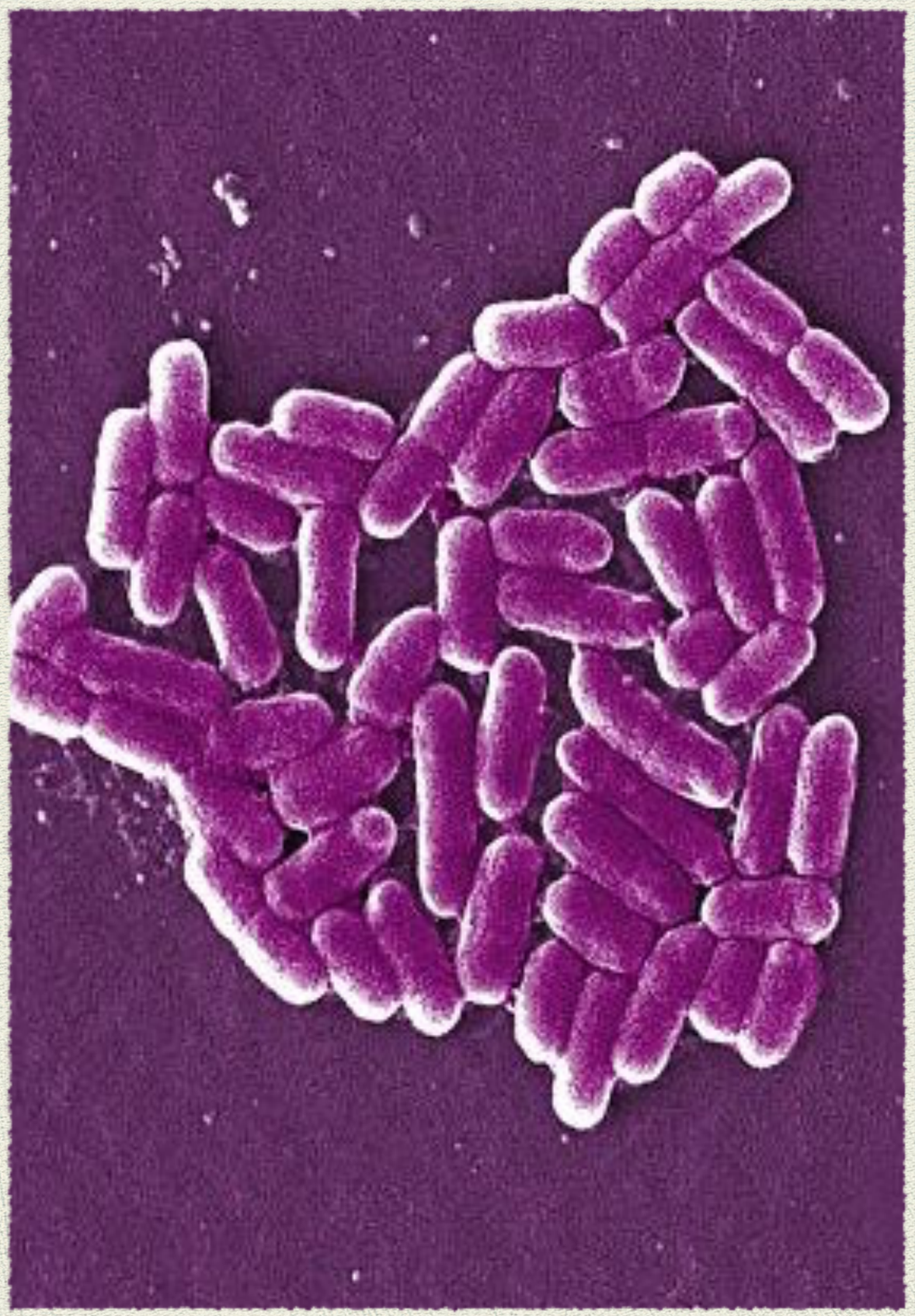
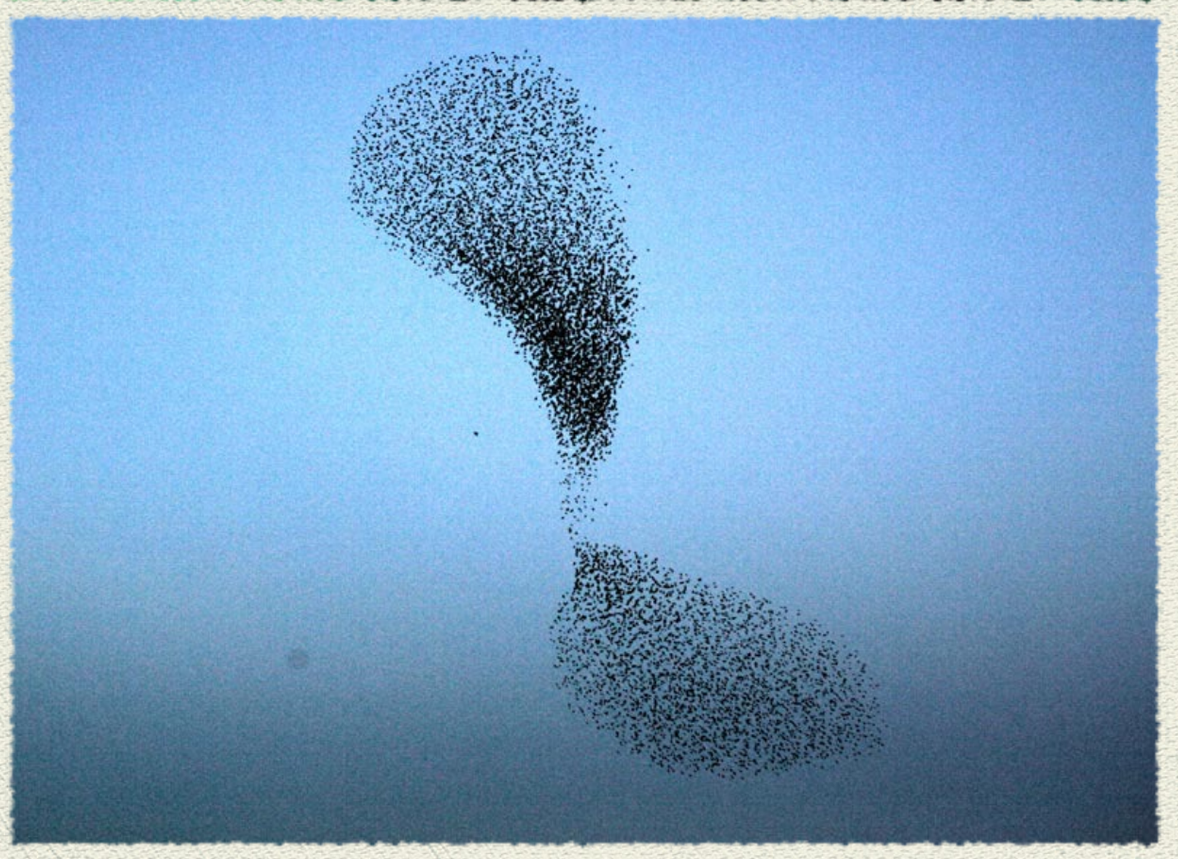






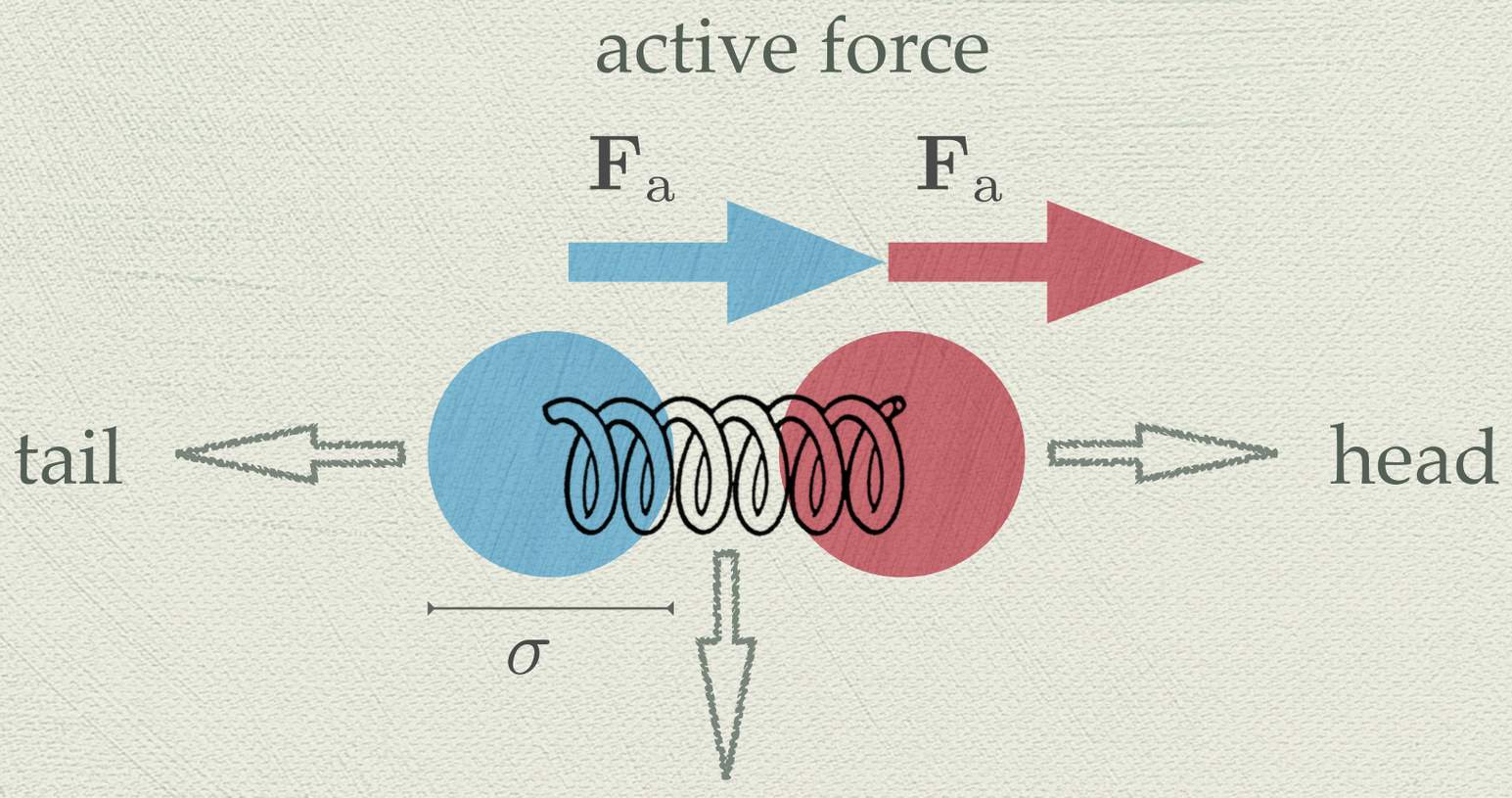


Active matter in 1 slide

- Systems: grains on a vibrating plate, Janus particles, bacteria, cytoskeleton, fish, birds, human beings…
- Models: run-and-tumble, Vicsek, field-theoretical (Toner & Tu…)…
- Experiments: tracers in active suspension…

(weightlifter's) dumbbell

(physicist's) dumbbell



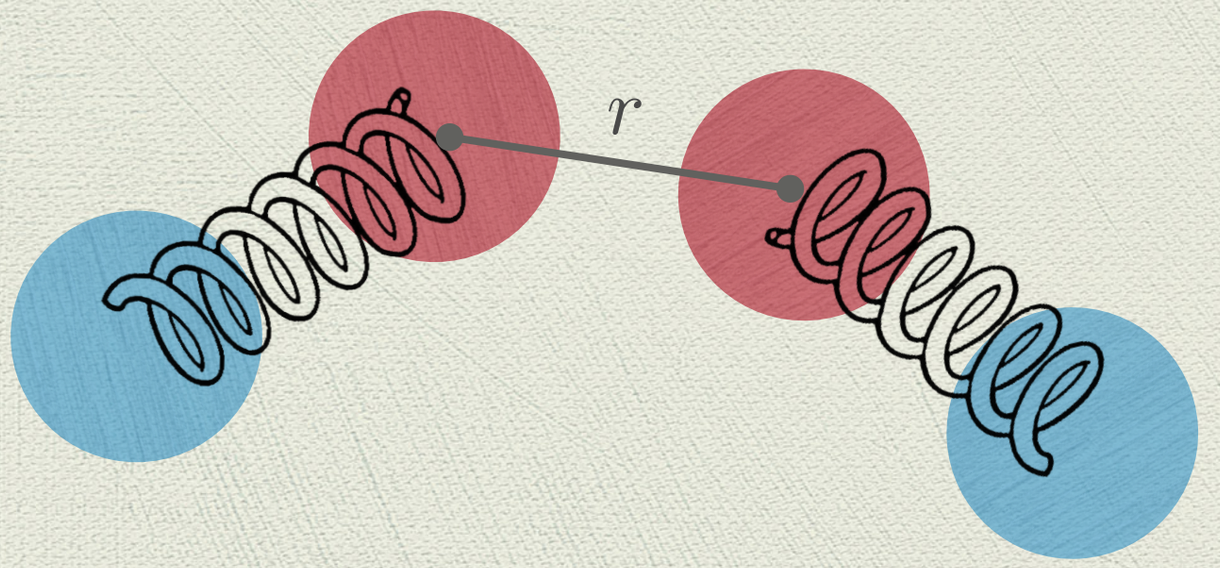
FENE spring

$$\mathbf{F}_{\text{fene}} = \frac{-k\mathbf{r}}{1-(r/r_{\max})^2}$$

Interacting dumbbells

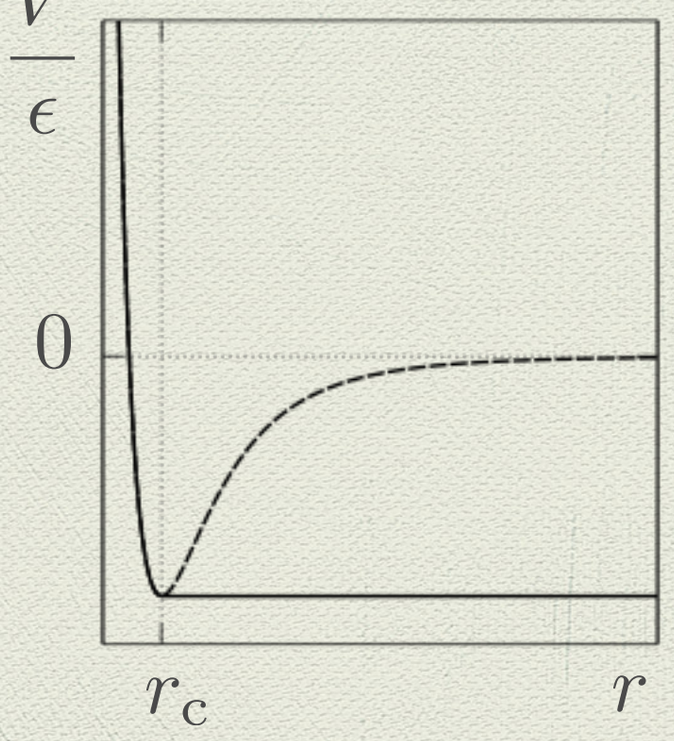
Weeks-Chandler-Anderson potential

$$V_{\mathrm{WCA}} = \begin{cases} V_{LJ}(r) & \text{for } r < r_{\mathrm{c}} \\ 0 & \text{for } r > r_{\mathrm{c}} \end{cases}$$



Lennard-Jones potential

$$V_{\mathrm{LJ}} = 4\epsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6} \right]$$



$$r_{\mathrm{c}} = 2^{1/6}\sigma \approx 1.122\sigma$$

Equations of motion

$$m\ddot{\mathbf{r}} = -\gamma\dot{\mathbf{r}} + \boldsymbol{\eta} - \mathbf{F}_{\mathrm{fene}} + F_{\mathrm{a}}\frac{\mathbf{r}-\mathbf{r}}{|\mathbf{r}-\mathbf{r}|} - \nabla V_{\mathrm{WCA}}$$

$$m\ddot{\mathbf{r}} = -\gamma\dot{\mathbf{r}} + \boldsymbol{\eta} + \mathbf{F}_{\mathrm{fene}} + F_{\mathrm{a}}\frac{\mathbf{r}-\mathbf{r}}{|\mathbf{r}-\mathbf{r}|} - \nabla V_{\mathrm{WCA}}$$

$$\langle \eta_i(t) \rangle = \langle \eta_i(t) \rangle = \langle \eta_i(t)\eta_j(t') \rangle = 0$$

$$\langle \eta_i(t)\eta_j(t') \rangle = \langle \eta_i(t)\eta_j(t') \rangle = 2\gamma k_{\mathrm{B}} T \delta_{ij}\delta(t-t')$$

Dimensionless numbers

Péclet number

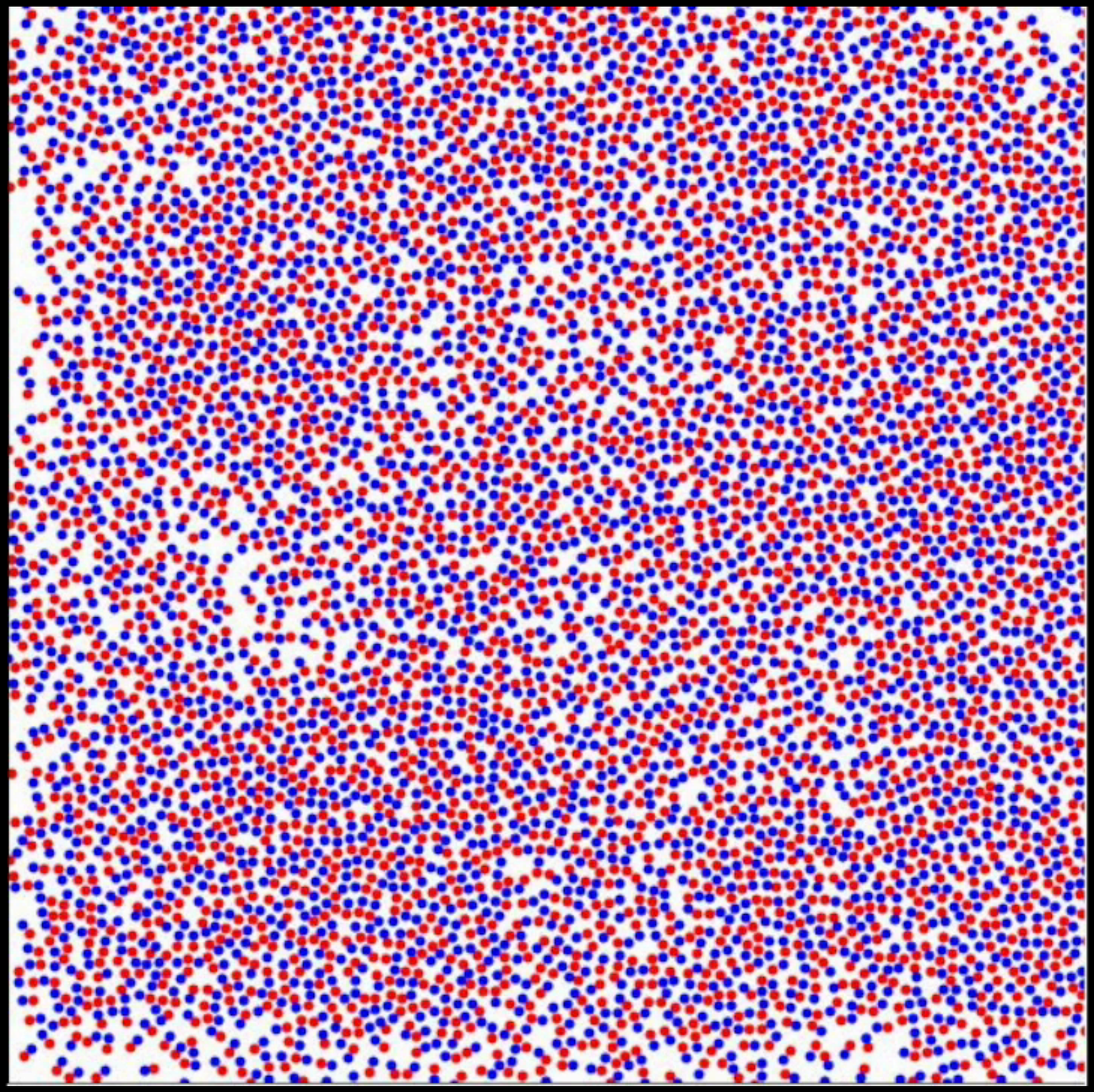
$$\mathrm{Pe} = \frac{2\sigma F_\mathrm{a}}{k_\mathrm{B}T}$$

Reynolds number

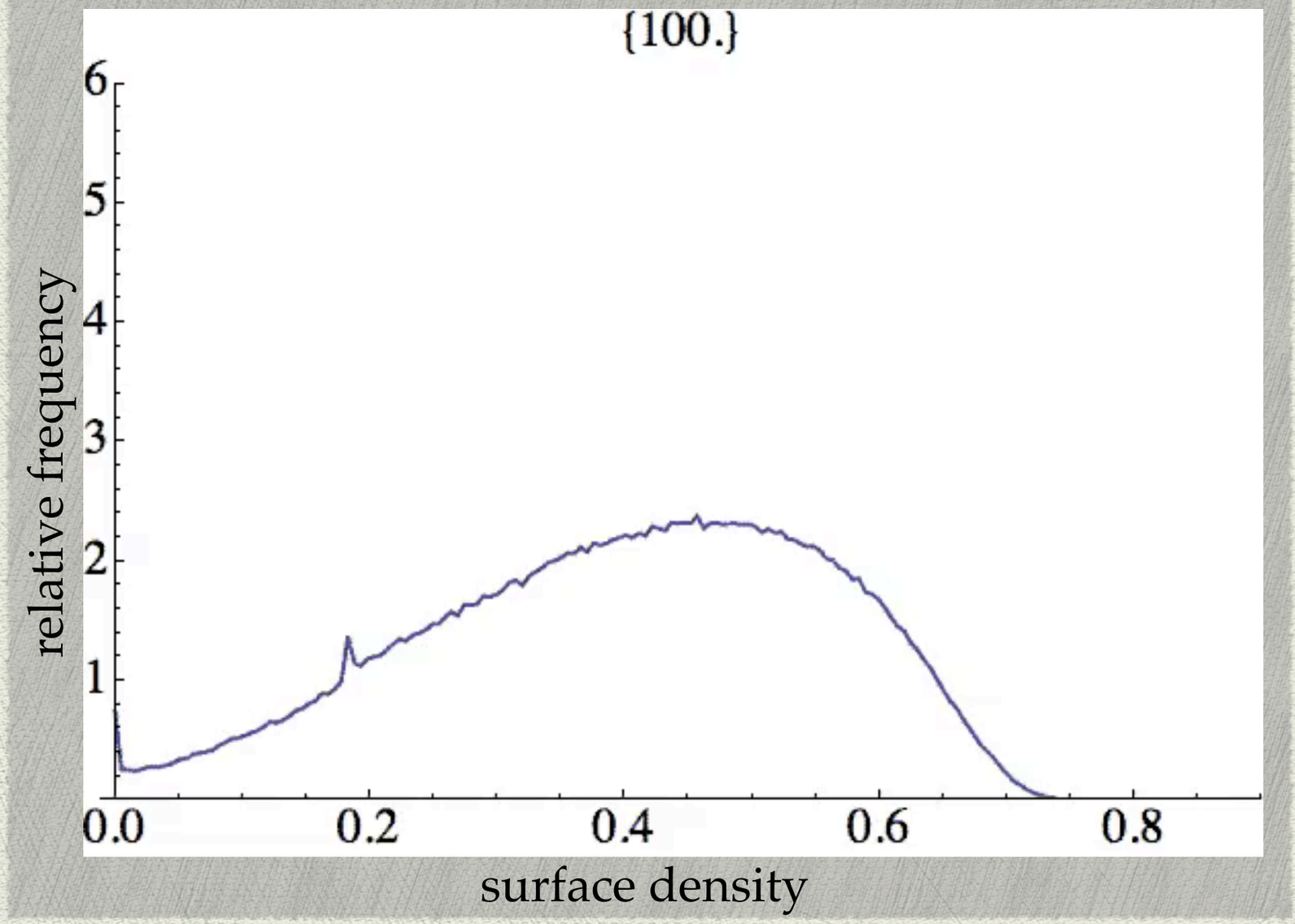
$$\mathrm{Re} = \frac{mF_\mathrm{a}}{\sigma\gamma^2}$$

Surface density

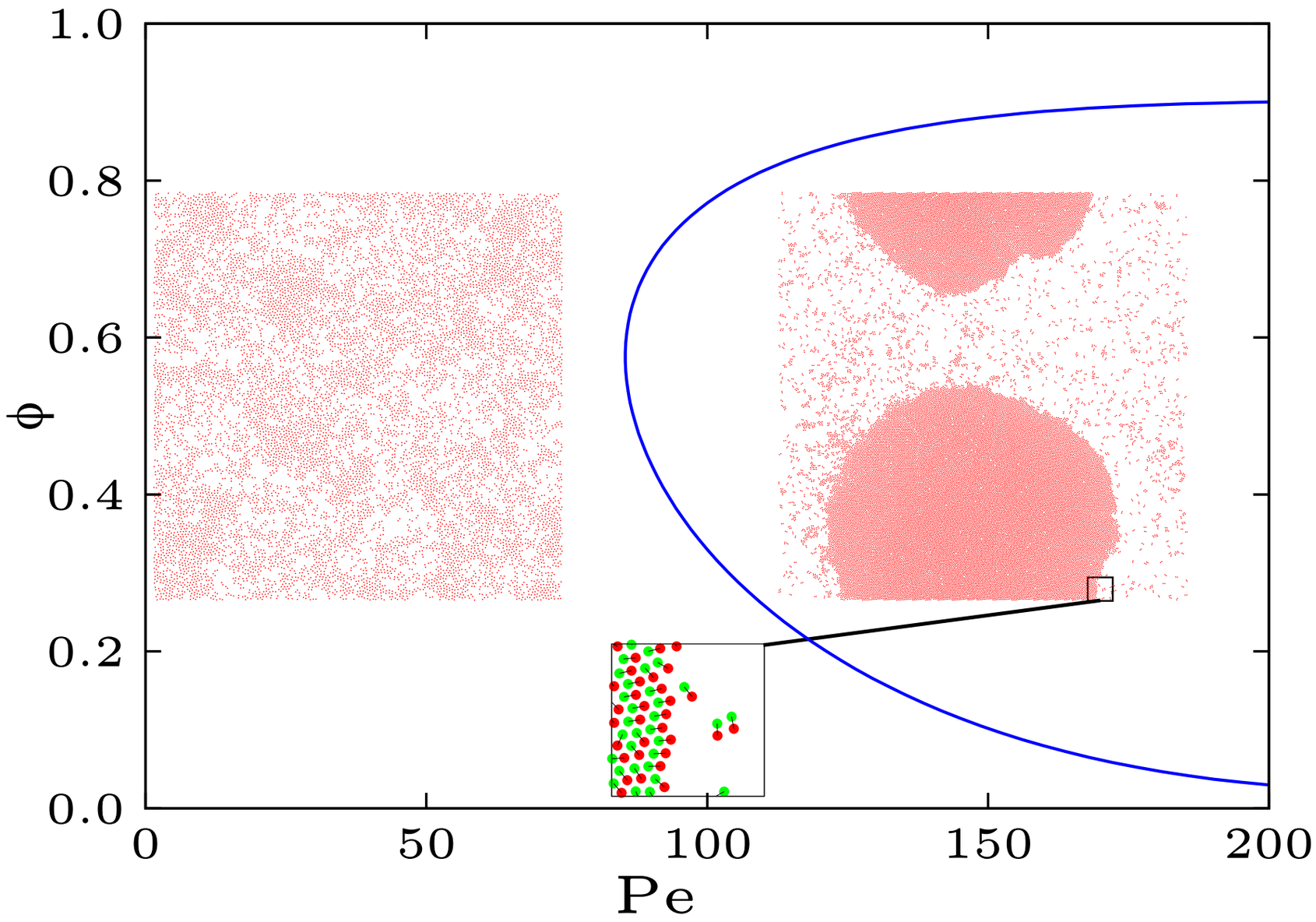
$$\phi = \frac{N\pi\sigma^2}{2A}$$



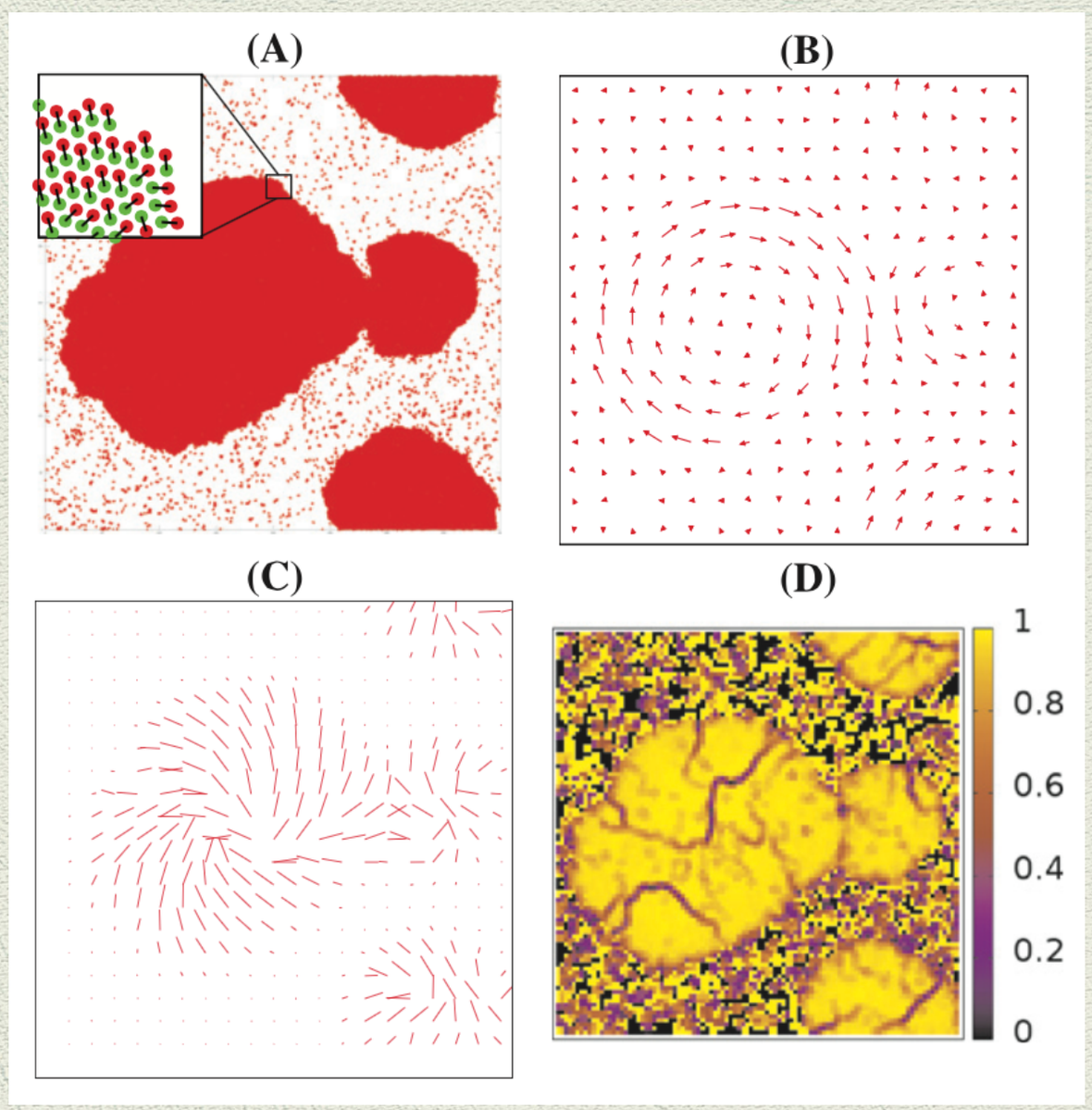
Motility-induced phase separation



Phase diagram

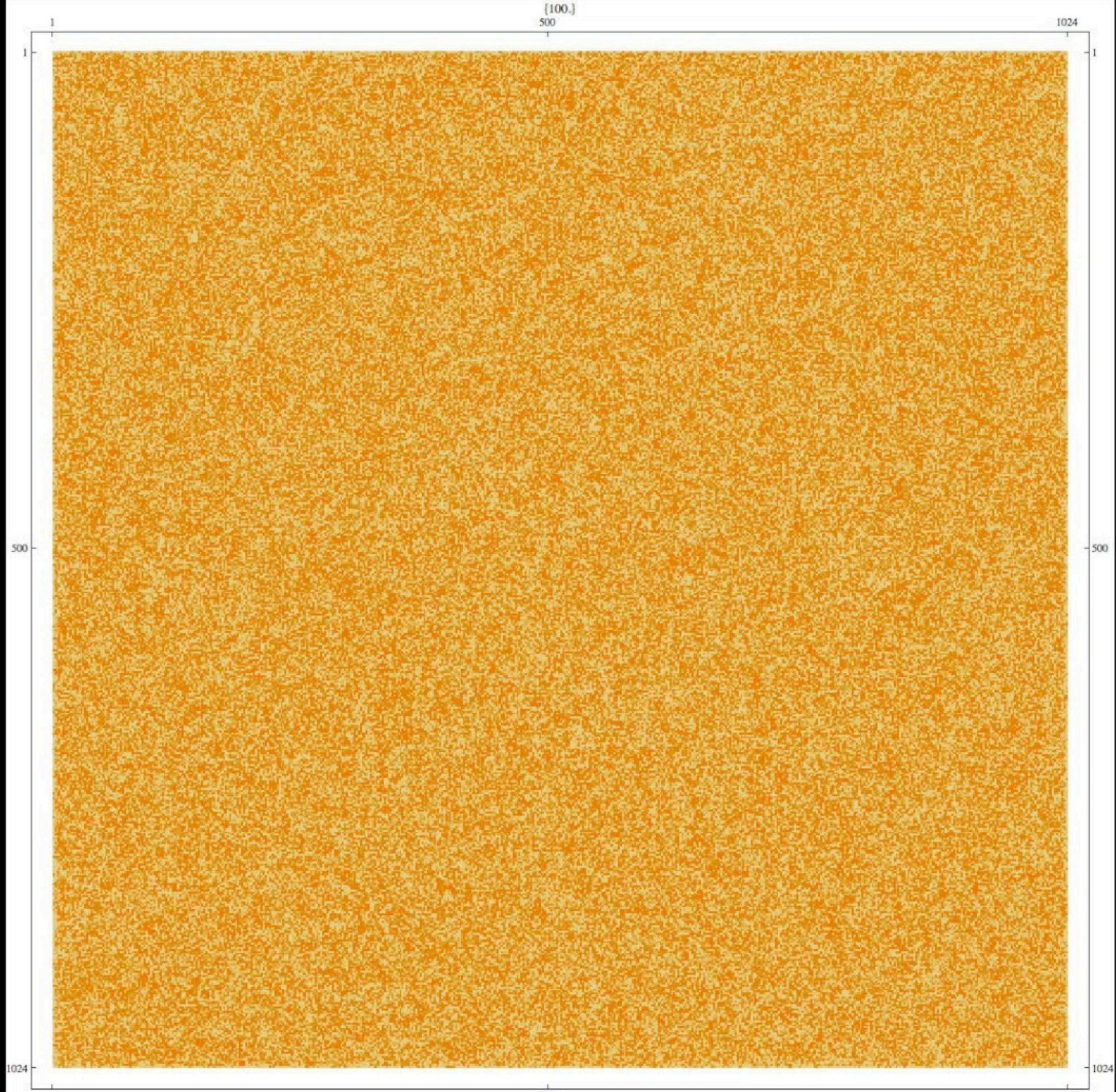


Vortices & spirals

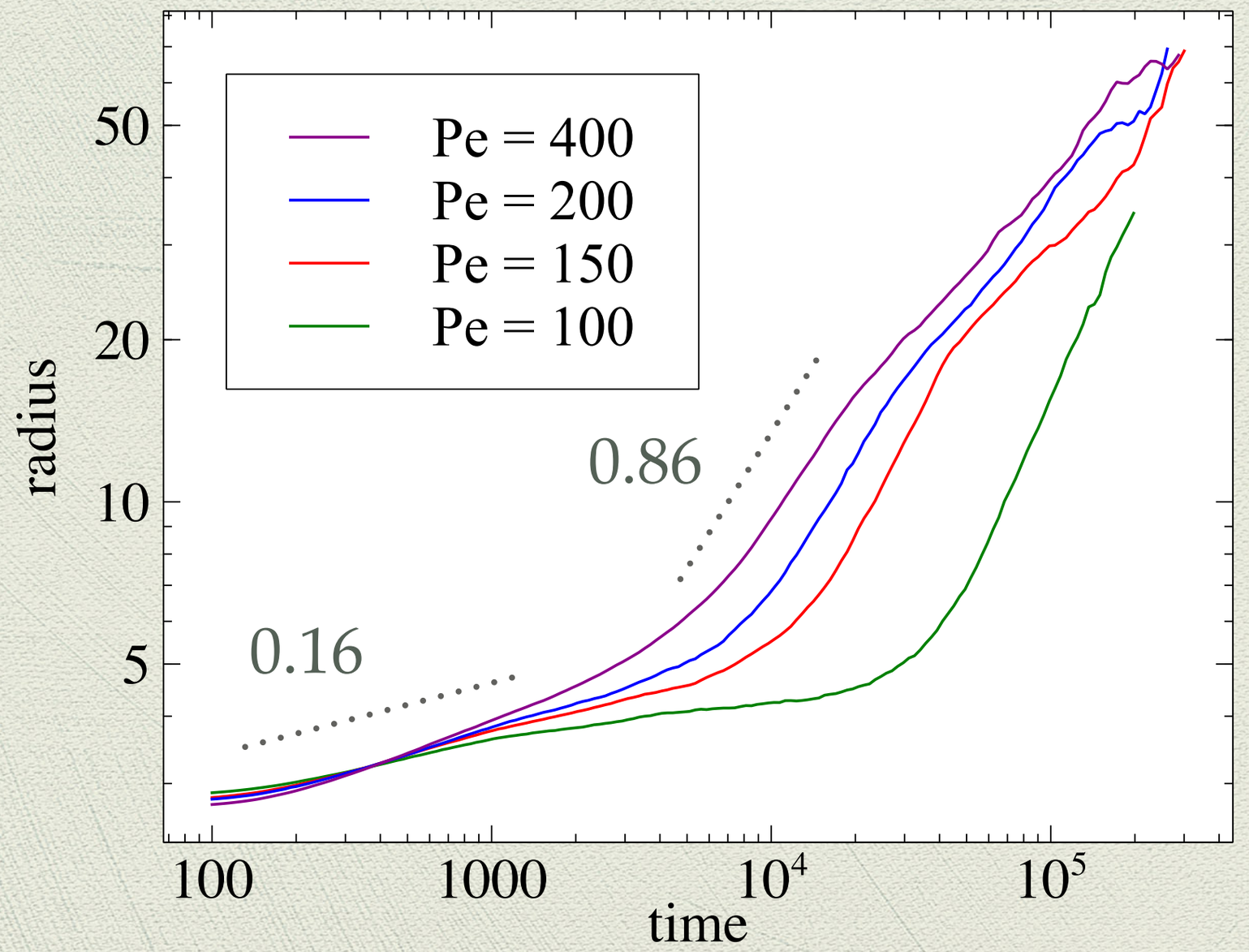


Suma et al. *EPL* **108** (2014): 56004

[100.]

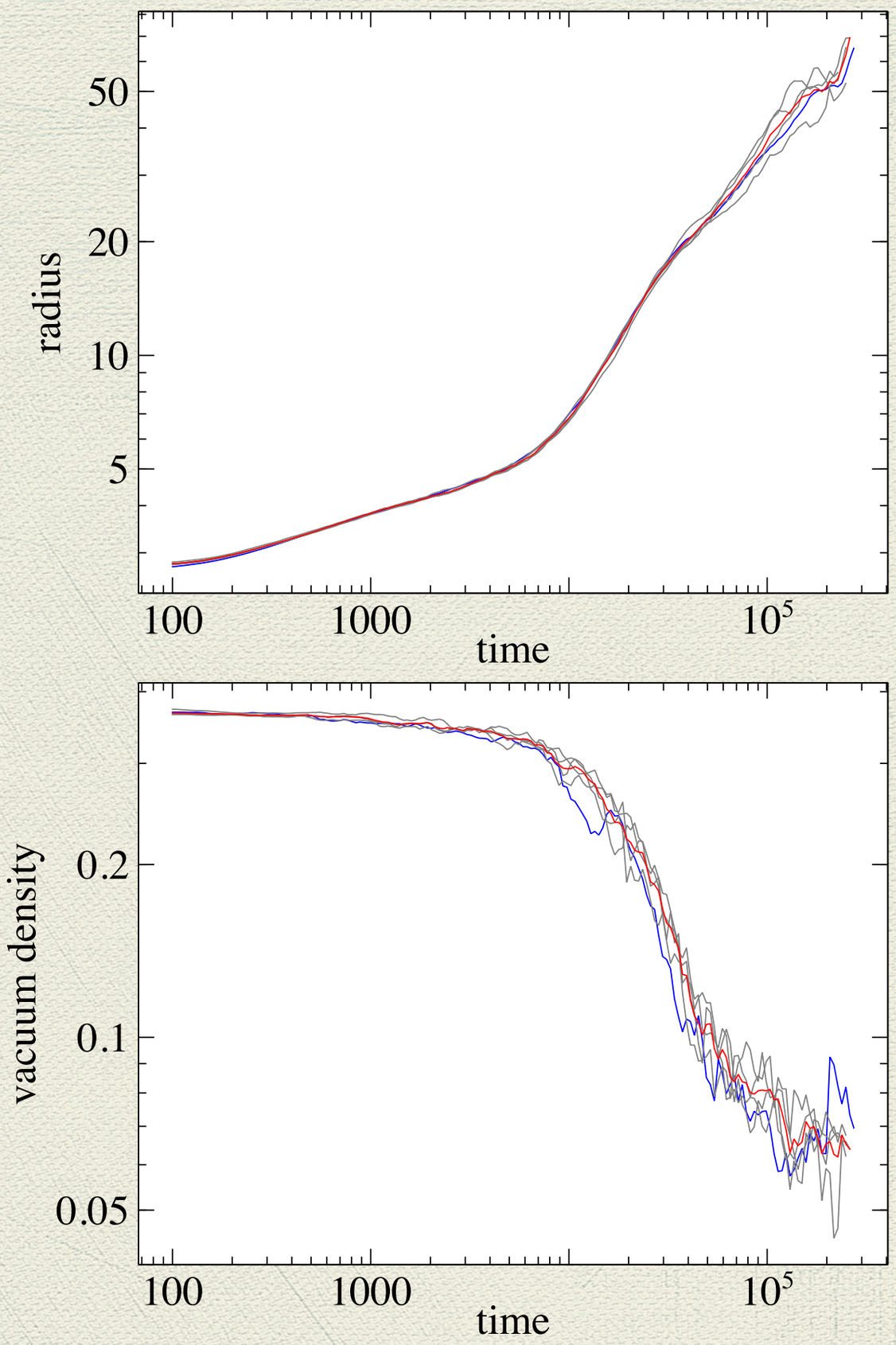


Typical cluster size



A possible explanation?

The "gas-like" regions take a very long time to reach their equilibrium density



References

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Thank you for your attention

and the organizers for their exquisite hospitality...