UNIVERSITÀ
DEGLI STUDI DI BARI
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Corso di Dottorato in Fisica XXXII ciclo

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ACTIVE PARTICLE SYSTEMS

Stationary and kinetics properties

SUMMARY

- ACTIVE MATTER
- DUMBBELL MODEL
- 2D HARD DISKS TRANSITIONS
- ACTIVITIES

ACTIVE MATTER

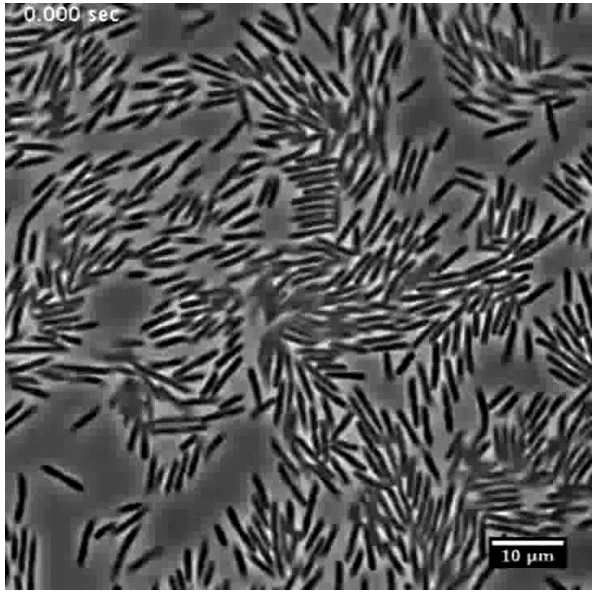
In active matter systems constituents consume energy from the environment and use it to displace.

Active matter is inherently

OUT OF EQUILIBRIUM

New behaviors:

ACTIVITY-INDUCED PHASE SEPARATION



ACTIVE MATTER

There are three ways to describe active matter

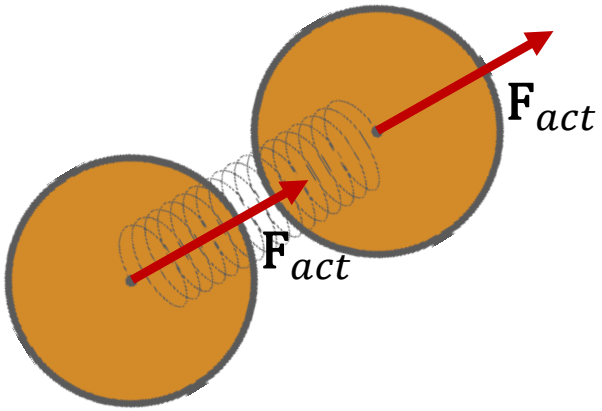
- MACROSCOPIC kinetic-like field models in the hydrodynamic limit[1][2]
- PARTICLE-SCALE stochastic models (Active Brownian Particles)[3]
- MICROSCOPIC fluid-dynamics[4]

[1] J. Toner and Y. Tu, **Phys. Rev. Lett.**, 1995.
[2] G. Gonnella, D. Marenduzzo *et al.*, **Comptes Rendus Physique**, 2015.
[3] T. Vicsek, et al., **Phys. Rev. Lett.**, 1995.
[4] A. Baskaran, M.C. Marchetti, **PNAS**, 2009.

ACTIVE MATTER

THE 2D DUMBBELL MODEL [1]

- γ friction, $\boldsymbol{\eta}$ uncorrelated Gaussian noise;
- $U_{WCA}(r)$ repulsive potential;
- $F_{FENE}(r)$ finite extensible non-linear force;
- $\mathbf{F}_{act,i}$ active force, constant in magnitude and directed along the main axis.

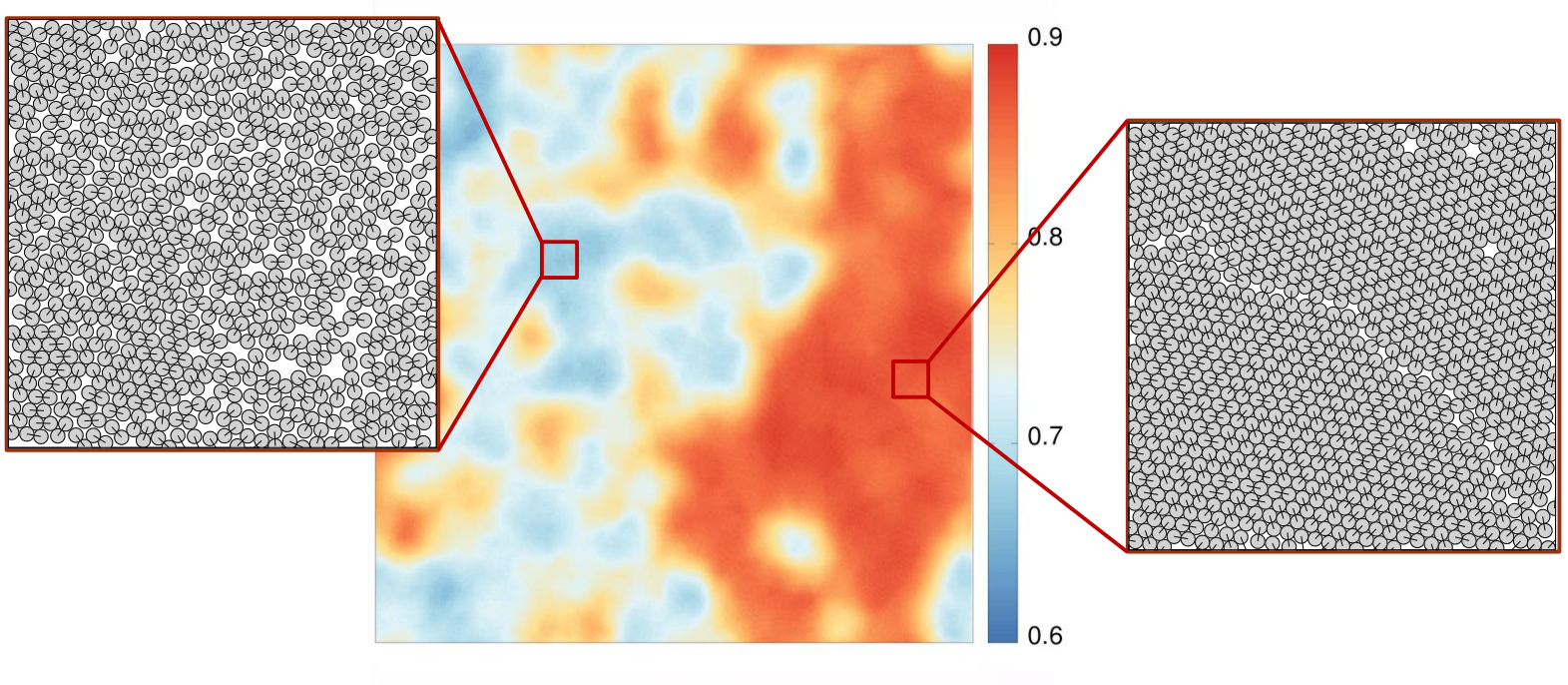


$$m\,\ddot{\boldsymbol{r}}_i(t) = -\gamma\dot{\boldsymbol{r}}_i(t) - \frac{\partial U_{FENE}}{\partial r_{i,i+1}}\hat{\boldsymbol{r}}_{i,i+1} - \sum_{j\neq i}^{2N}\frac{\partial U_{WCA}}{\partial r_{ij}}\hat{\boldsymbol{r}}_{i,j} + \sqrt{2\gamma k_B T}\,\boldsymbol{\eta}_i + \mathbf{F}_{act,i}$$

[1] A. Suma, G. Gonnella, *et al.*, Phys. Rev. E, 2014.

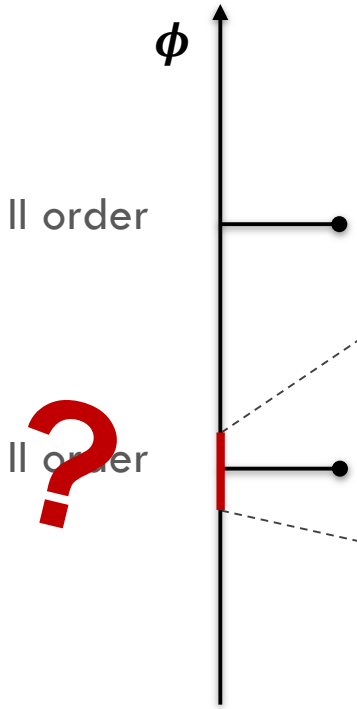
ACTIVE MATTER

PHASE SEPARATION IN THE DUMBBELL MODEL [1]



[1] L.F. Cugliandolo, P. Digregorio, G. Gonnella, A. Suma, **arXiv**, 2016.

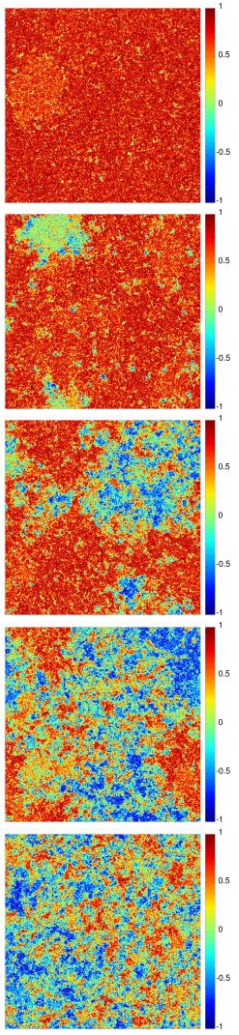
2D PASSIVE TRANSITIONS [1] [2]



SOLID
- quasi-long-range positional order
- long-range orientational order

HEXATIC
- short-range positional order
- quasi-long-range orientational order

LIQUID
- short-range order

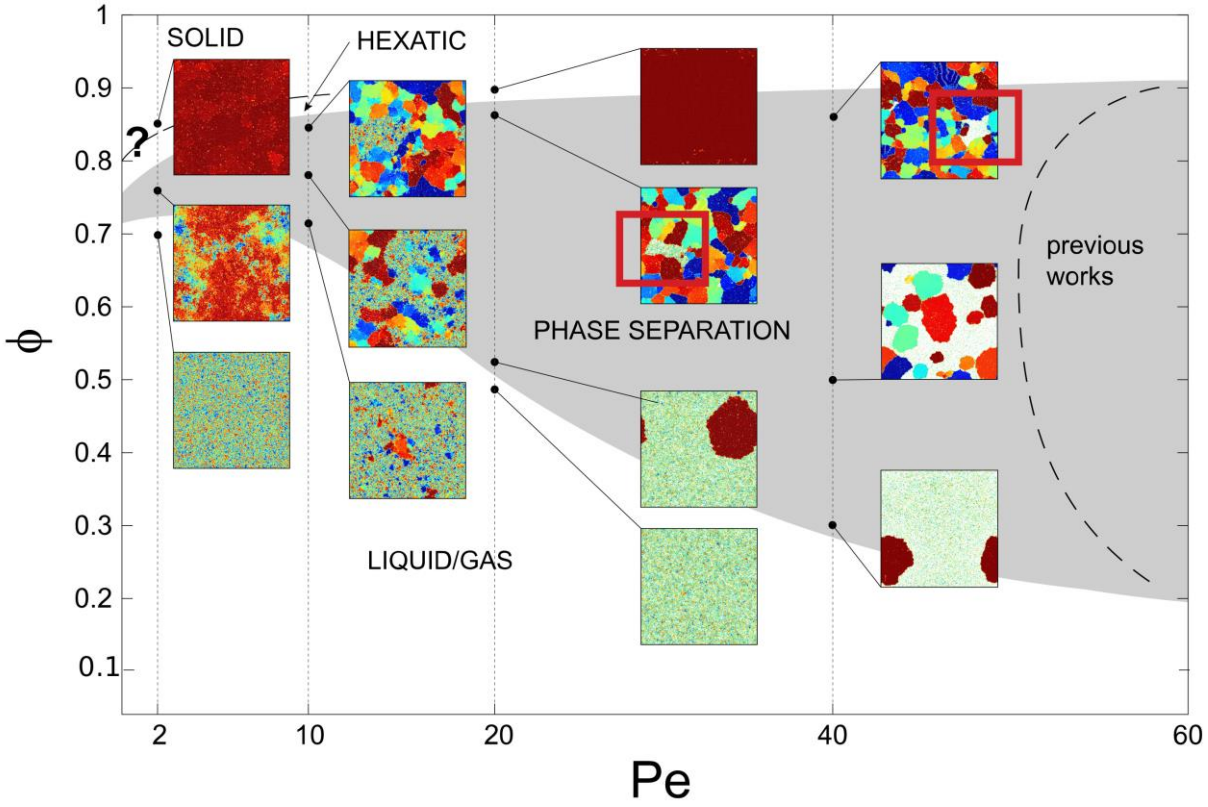


[1] J. M. Kosterlitz , D. J. Thouless, **Journal of Physics C,** 1973

[2] B. I. Halperin and David R. Nelson. **Phys. Rev. Lett.**, 1978.

[3] L.F. Cugliandolo, P. Digregorio, G. Gonnella, A. Suma, **arXiv**, 2016.

PHASE DIAGRAM [1]



[1] L.F. Cugliandolo, P. Digregorio, G. Gonnella, A. Suma, arXiv, 2016.

ACTIVITIES IN THE FIRST YEAR

- PASSIVE LIMIT of the dumbbell system and of other systems with pure repulsive short-range interactions (spherical particles, rods)
- THERMODYNAMICS in the passive limit [1]
  - Free energy scaling
  - pressure
  - correlations
- PRESSURE in active systems [2]

[1] M. Engel, W. Krauth, *et al.,* **Phys. Rev. E,** 2013.
[2] F. Ginot, D. Levis, *et al.*, **Phys. Rev. X**, 2015.

NEXT YEARS

- KINETIC PROPERTIES in the dumbbell system
  - coarsening
  - effects of the shear in the coarsening
  - tracer dynamics (diffusion coefficient, etc.)
- FLUID-DYNAMICS effects on the system