# Cholesteric Liquid Crystals & Active Emulsions

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# Summary

- General Framework
- Lattice Boltzmann Method for Liquid Crystals in three-dimensional geometries
- Cholesteric Liquid Crystals
- Active Emulsions
- Active Turbulence

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# General Framework

- Model & Methods of numerical fluid dynamics: coarse grained approach
- Generalized Navier-Stokes equation
- Binary mixtures ⟶ Concentration scalar field $\varphi$
- Anisotropic contributions: vector/tensor order parameters $\Psi$

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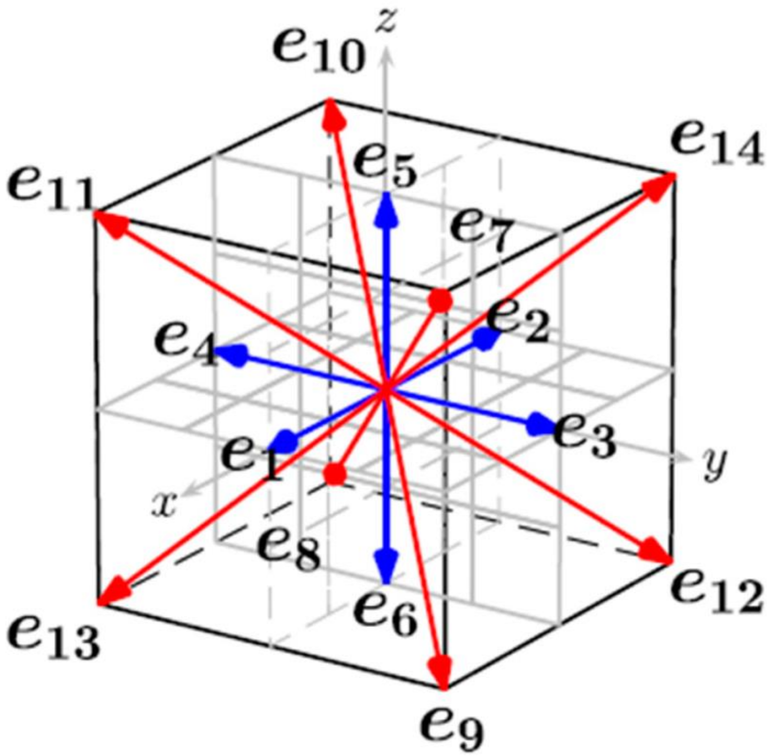
$$\partial_t\Psi + \vec{v}\cdot\nabla\Psi + S = \Gamma\frac{\delta F}{\delta\Psi}$$

# 3d Lattice Boltzmann Method

- Boltzmann Equation → Discretized time, space and velocity
- Distribution functions $f_i(\vec{x}_\alpha, t)$
- Physical observables $\rho(\vec{x}_\alpha, t) = \sum_i f_i(\vec{x}_\alpha, t)$ $\rho\vec{v} = \sum_i \vec{e}_i f_i(\vec{x}_\alpha, t)$
- DF dynamics
  - Collision (BGK approximation)

$$f_i^{coll}(\vec{x}_\alpha, t) = f_i(\vec{x}_\alpha, t) - \frac{1}{\tau}\left[f_i(\vec{x}_\alpha, t) - f_i^{eq}(\vec{x}_\alpha, t)\right]$$

  - Streaming $f_i(\vec{x}_\alpha + \vec{e}_i\Delta t, t + \Delta t) = f_i^{coll}(\vec{x}_\alpha, t)$
- Equilibrium DF → Expansion at II order in $\vec{v}$ → Recover continuum equations



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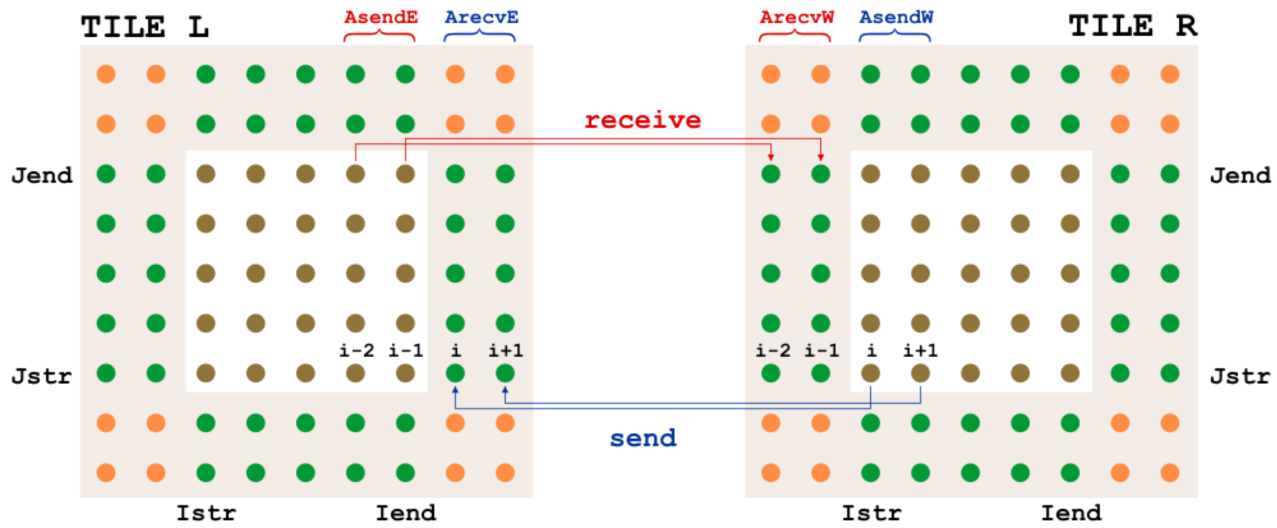
Be Wise… Parallelize!!!




- Summer school on Parallel Computing – Cineca (BO)
- Advanced School on Parallel Computing – Cineca (BO)

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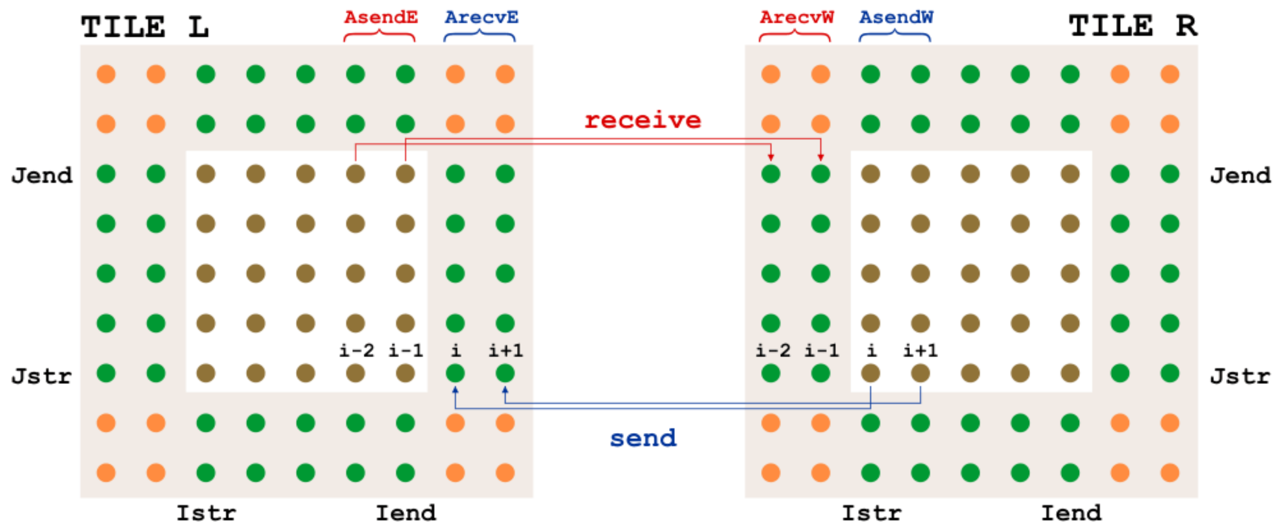
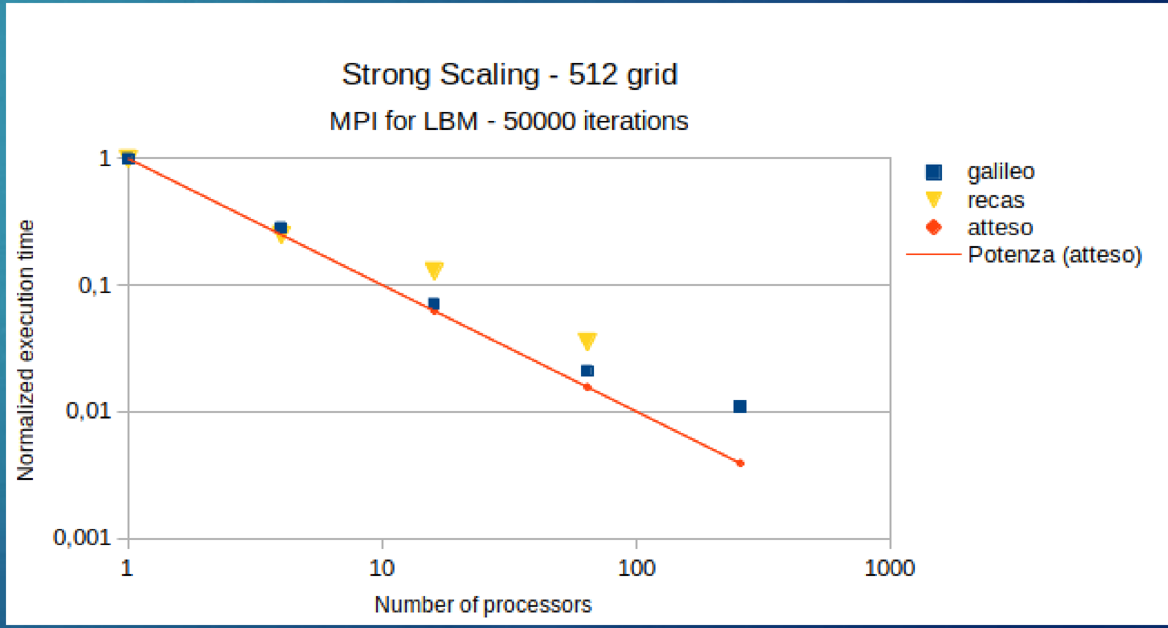
- Massage Passing Interface
- ~ 40Gb of Memory
- ~ 3y of CPU

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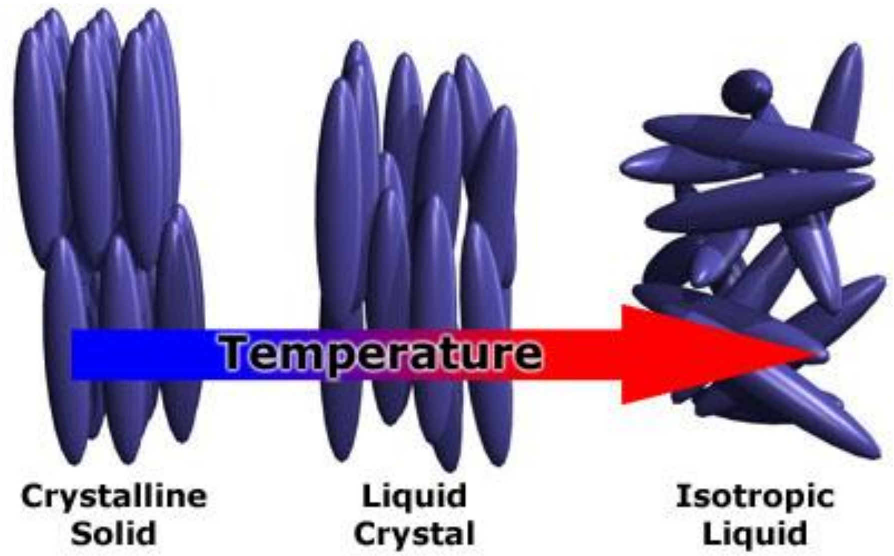
# Cholesteric Liquid Crystals

- Long chained molecules in solution
- Lost traslational order, preserved directional order



# Cholesteric Liquid Crystals

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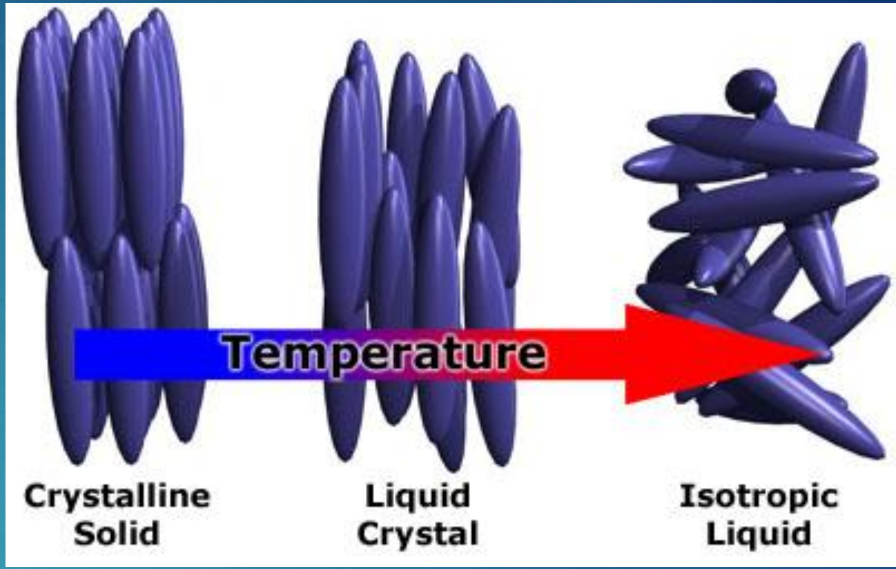
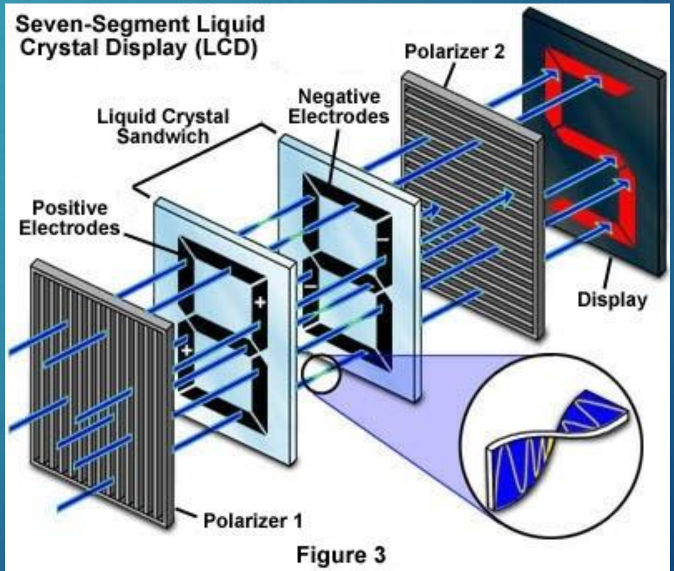
- Chirality ⟶ Cholesteric LC
- Optical properties

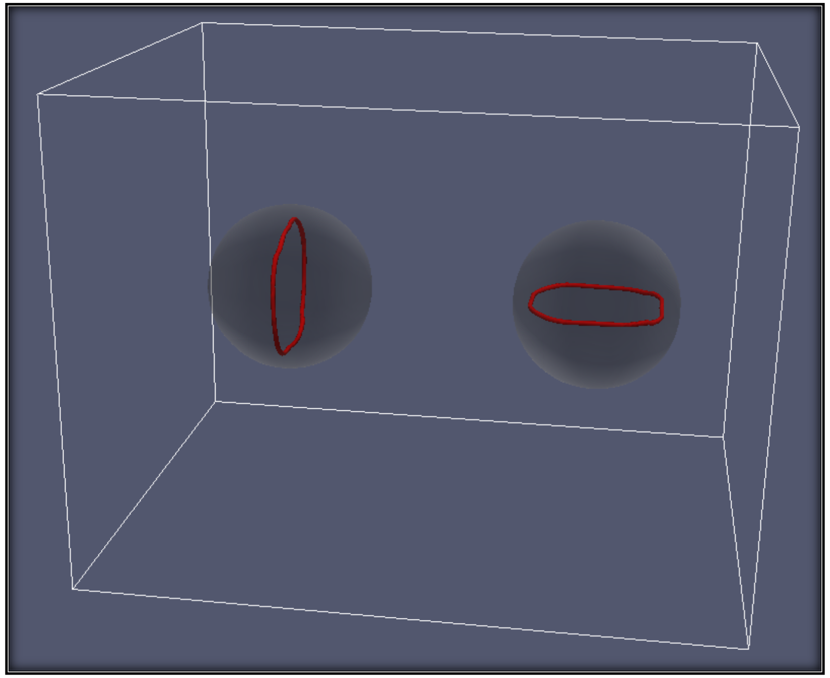


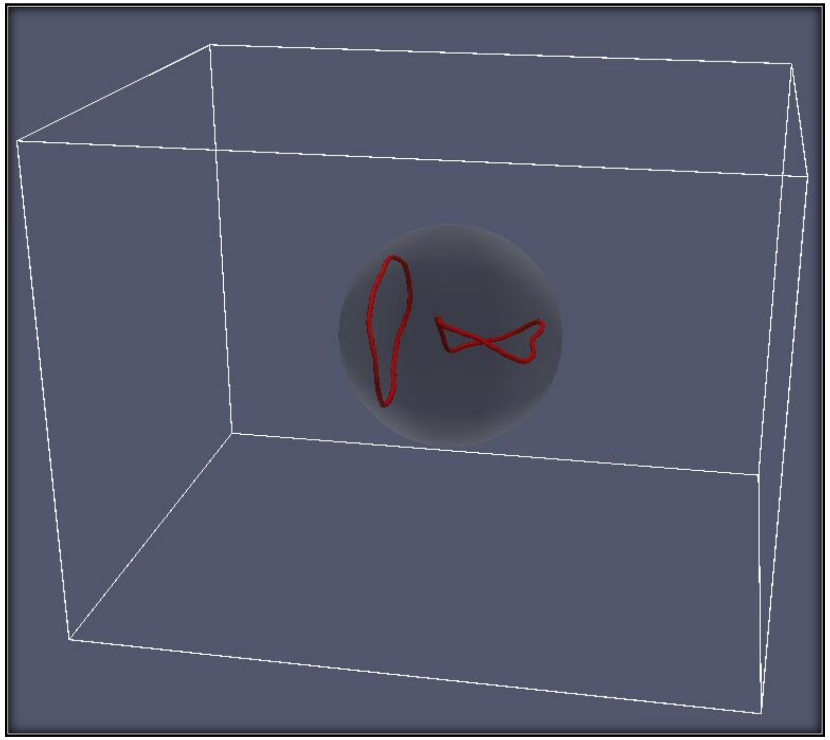




# Defects in CLC droplets

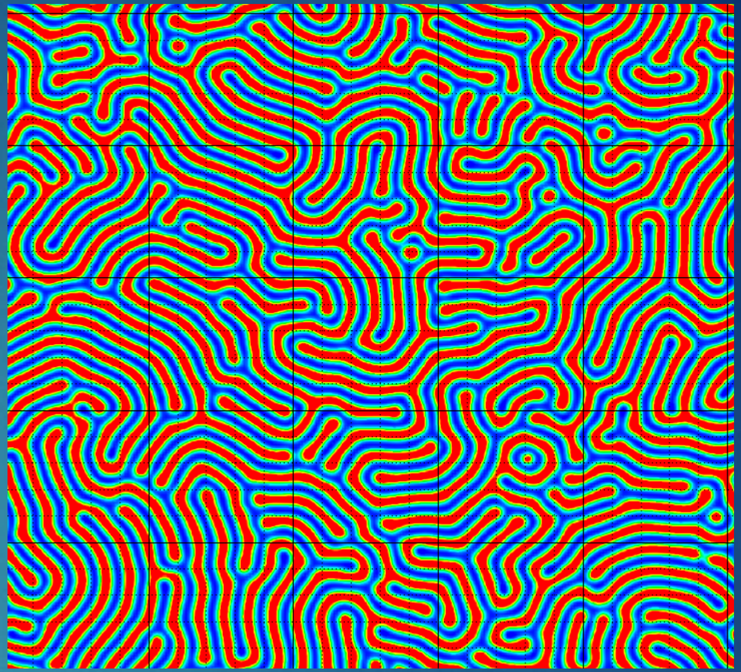
- Fundamental for optical properties
- Strong dependence on geometry and boundary condition

- Relaxing dynamics*
- Merging droplets*
- Droplets under shear
- Switching dynamics under electric field





# Active Emulsions



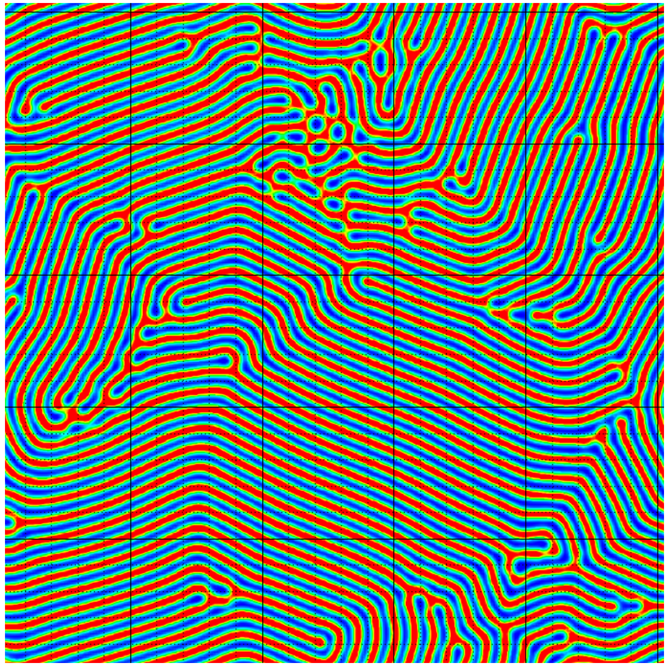
- Active matter: energy injection on small scales
  - Bacteria Suspensions
  - Cytoskeleton extracts
- Polar order
- Confinement of active behavior

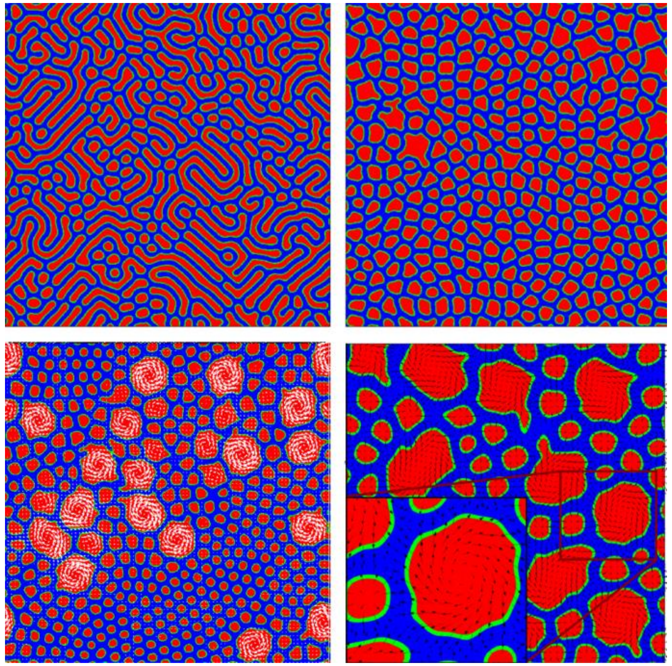
$$F = \int dV \left[ \frac{a}{4\,\varphi_{cr}} \varphi^2 (\varphi - \varphi_0)^2 + \frac{k_\varphi}{2} (\nabla \varphi)^2 + \frac{c}{2} (\nabla^2 \varphi)^2 + \frac{\alpha}{2} \varphi \vec{P}^2 + \frac{\alpha}{4} \vec{P}^4 + \frac{k_P}{2} \left(\nabla \vec{P}\right)^2 + \beta \vec{P} \cdot \nabla \varphi \right]$$

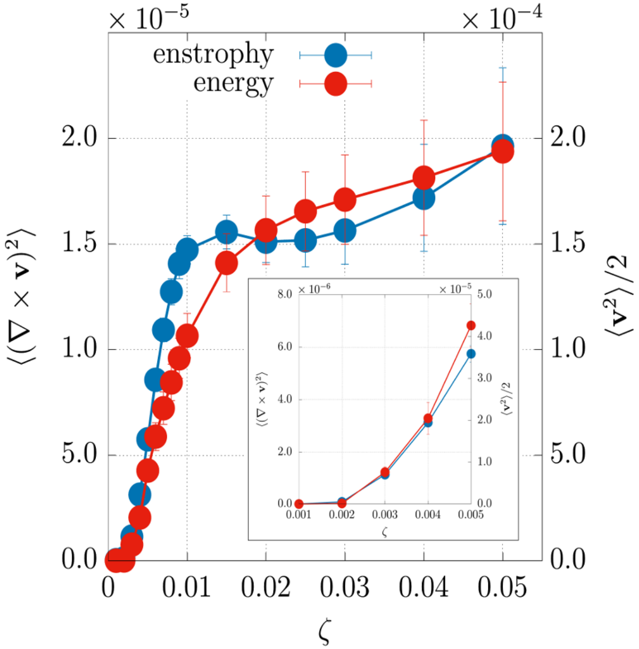
- Lamellar phase if $a < \frac{k_\varphi^2}{4c} + \frac{\beta^2}{k_P}$ $\quad k_\varphi < 0\,, c > 0$
- Active stress tensor $\sigma^{actve} = -\zeta \varphi \vec{P} \otimes \vec{P}$

# Results

- Activity favours ordering
- Transition towards mesoscale turbulence
- Wealth of different morphologies



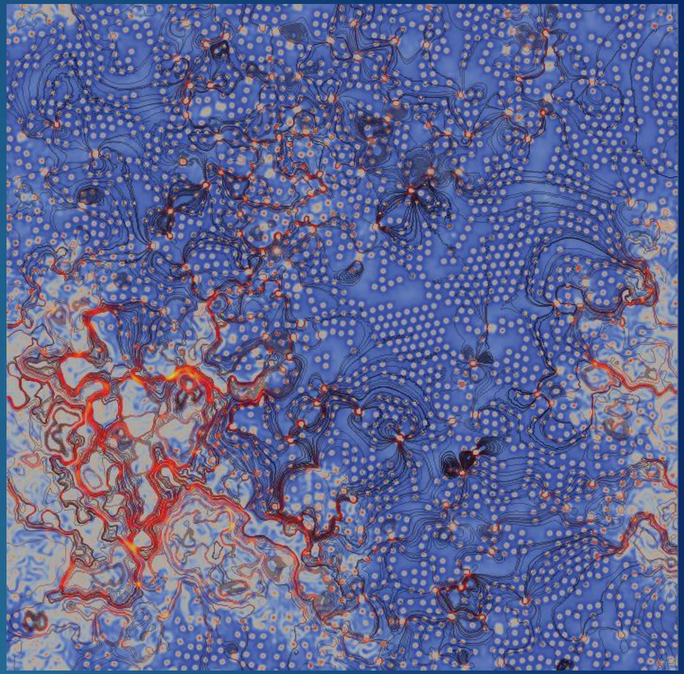





- G.Negro,L.N.Carenza,P.Digregorio,G.Gonnella,A.Lamura *Morphology and flow patterns in highly asymmetric active emulsion, Physica A, Vol. 503, 2018, 464-475*
- F.Bonelli,L.N.Carenza,G.Gonnella,D.Marenduzzo,E.Orlandini,A.Tiribocchi *Lamellar ordering, droplet formation and phase inversion in exotic active emulsions,* **Accepted with minor revisions Scientific Reports (Nature)**
- L.N.Carenza,G.Gonnella,A.Lamura,G.Negro,A.Tiribocchi *Lattice Boltzmann Methods and Active Fluids,* **Submitted to EPJ**

# Active Turbulence

- Energy injection on small scales ⟶ Mesoscale turbulence
- What is new?



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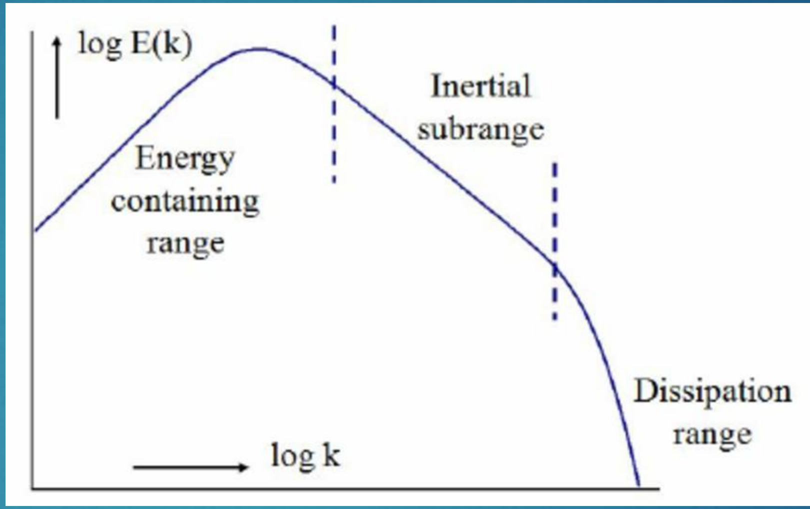
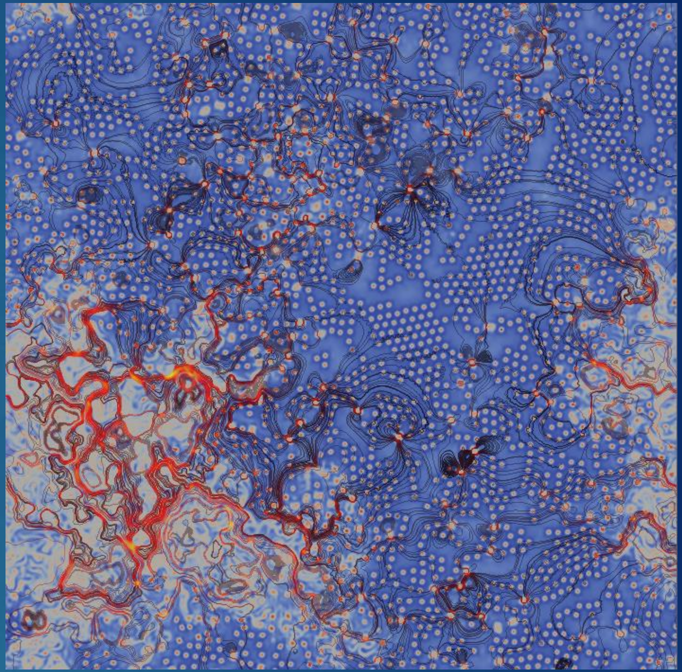
    - High Reynolds number
    - Hydrodynamics non-linearities
    - -5/3 spectrum (universal behavior)



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  - KOLMOGOROV TURBULENCE :
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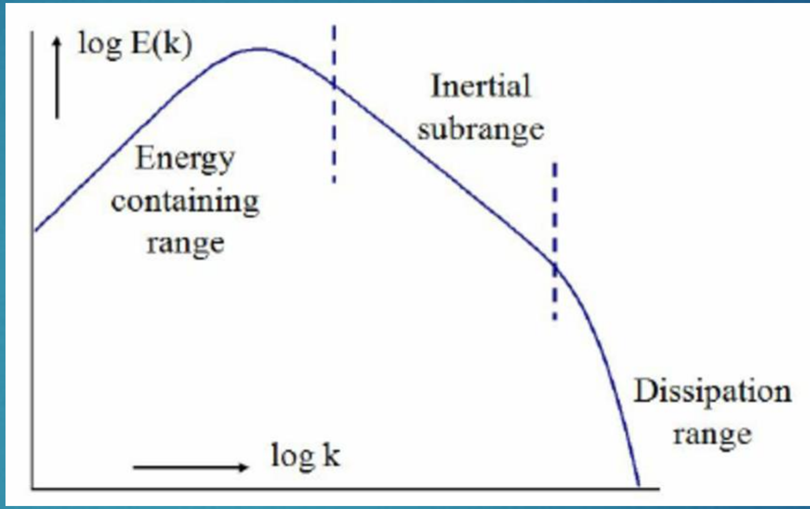
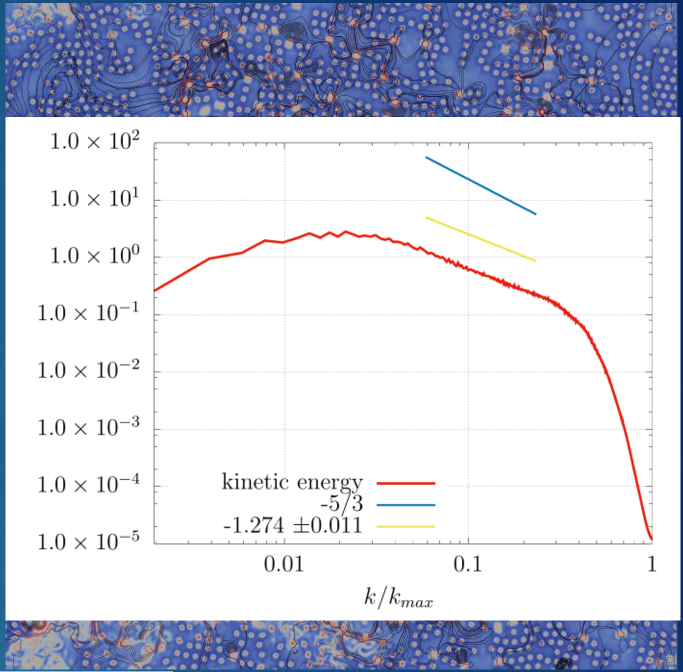
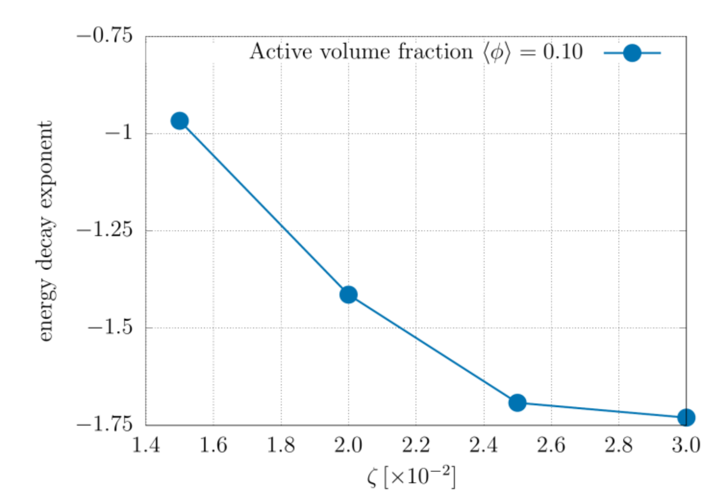
  - ACTIVE TURBULENCE
    - Low Reynolds number
    - Complex coupling source/sink power terms
    - No universal behavior



# Exams and Schools

## PhD COURSES

- How to prepare a technical speech in English
- Management and knowledge of European research model and promotion of research results
- Introduction to parallel Computing and GPU Programming using CUDA
- C++
- Atom-photon interactions
- Standard model and beyond
- Linear stability analysis*
- Computational fluid dynamic*

## PhD SCHOOLS

- Summer school on Parallel Computing – Cineca (Bologna)
- Advanced School on Parallel Computing – Cineca (Bologna)
- XXX National Seminar of Nuclear and Subnuclear Physics "Francesco Romano"  OTRANTO

Courses labelled with * are being erogated.

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questions?