# A coupled model for active gel hydrodynamics

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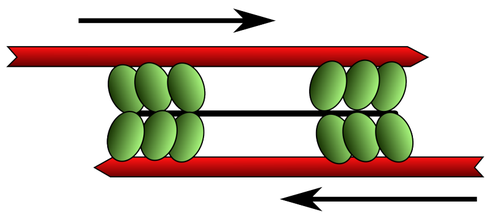
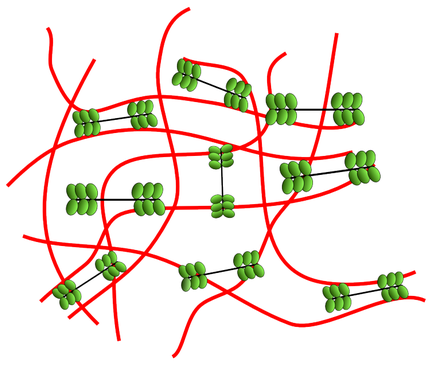
## 1. Introduction

**Active soft matter** is kept **out of thermodynamic equilibrium** by an internal energy source, normally ATP hydrolysis in a biological context.

For example **active gels** such as actomyosin play an important role in the cell cytoskeleton, controlling **motility** and **cell division**.



Small clusters of the **myosin** molecular motor form, and interact with a network of **actin** filaments.

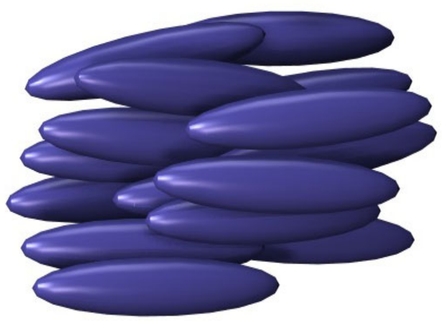


In the cell cytoskeleton, **actin** can form an entangled **network**: **myosin** then produces **contractile stresses**, which we model using the following coarse-grained picture…

## 2. Model

### Q (active nematics)

Active materials can form ordered phases, with broken symmetries similar to those of **nematic** liquid crystals



We adapt a liquid crystal model to **coarse-grain** the effect of many apolar active particles

**Q** describes local orientation; a constitutive relation **couples orientation with flow**

$$D_t\mathbf{Q} = f(\mathbf{Q}, \nabla\mathbf{u})$$

$$\rho\left(\partial_t + \mathbf{u}.\nabla\right)\mathbf{u} = \nabla.\left(\Pi_\mathbf{Q} + \Pi_\mathbf{C} + \eta\left(\nabla\mathbf{u} + \nabla\mathbf{u}^T\right)\right)$$

$\rho(\partial_t + \mathbf{u}.\nabla)\mathbf{u}$ → **0** in the **zero Re limit**

### C (polymeric background) NEW!

A simple polymeric model describes the **cytoskeletal background** in which our gel sits

constitutive relation couples conformation tensor **C** to flow

$$D_t\mathbf{C} = g(\mathbf{C}, \nabla\mathbf{u})$$

### u (velocity field)

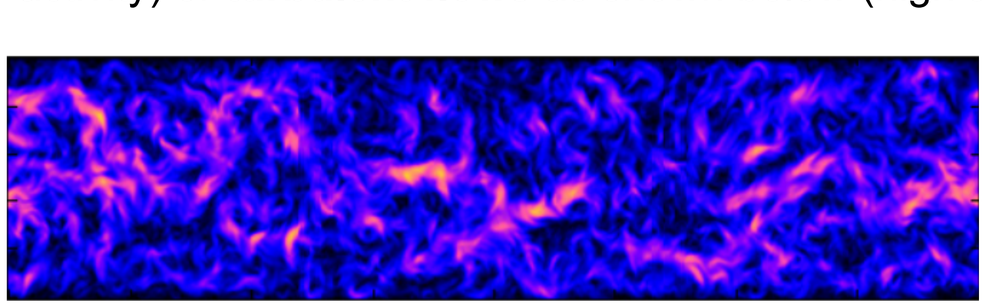
Implicit coupling between **Q** and **C** i.e. **only** through **flow field**

in zero Re limit, **velocity field u** reacts instantly to stresses from **Q** and **C**

## 3. Q (active nematics) only

**1D** at high enough activity (*i.e.* energy input), the system **spontaneously flows**, with a net throughput.

**2D** these **destabilise** forming either **roll-like structures** (low activity) or **turbulent flows** as shown below (high activity).



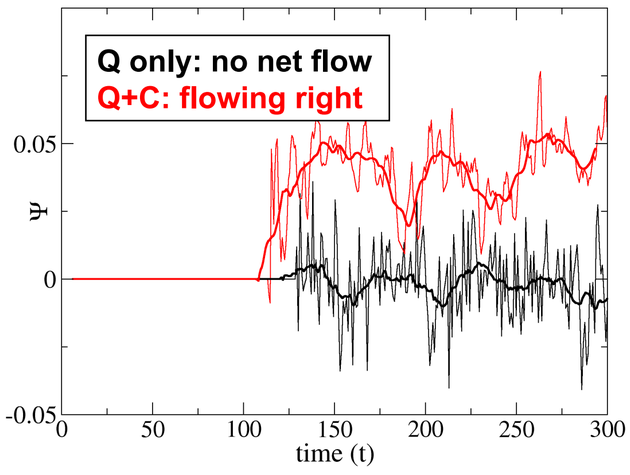
**a chaotic flow state**

*colour: magnitude of velocity*

**A surprising result:** in the limit **Re → 0** considered here, we normally expect *laminar* flows. However both simulation and experiment find examples of **activity driven turbulence**.

However, this changes if we add in polymeric background **C**…

## 4. Q (active) + C (polymer background)

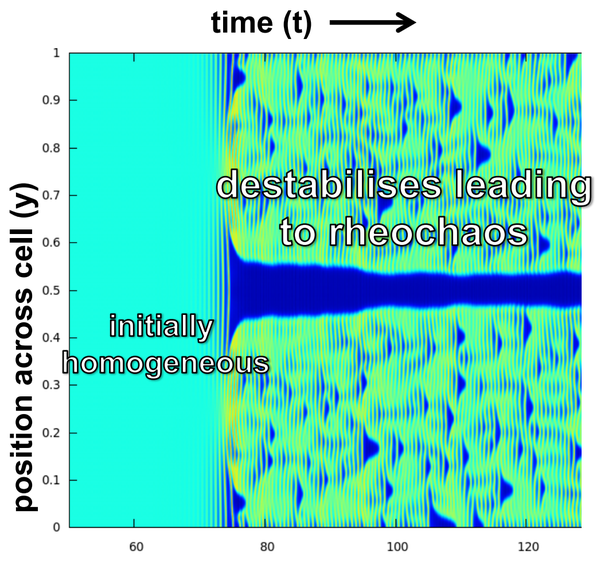



**Add polymer background:** in 2D, states with net throughput can be **restabilised**.

**Symmetry of the system** is **spontaneously broken** leading to net flow in a randomly chosen direction.

With added **polymer**, the model has two competing interactions (from both **Q** and **C**): this has important rheological consequences.

**e.g.** shear active matter between two parallel plates in 1D: in some regimes we find an **instability** where flow (colour map right) exhibits spatiotemporal chaos or **rheochaos**.




colour denotes local shear rate ($\dot{\gamma}$), blue low, red high

## 5. Outlook

Need to understand exactly what effect polymer **C** is having: examine flow fields, time/space correlation functions etc.

We could use the same formalism to describe (at very different length scales) swarming motion in bacteria, or even passive liquid crystals suspended in polymer: active materials are a great example of **universality**!