Title: Dynamics of the magnetic disc in nematic liquid crystal under the action of magnetic field

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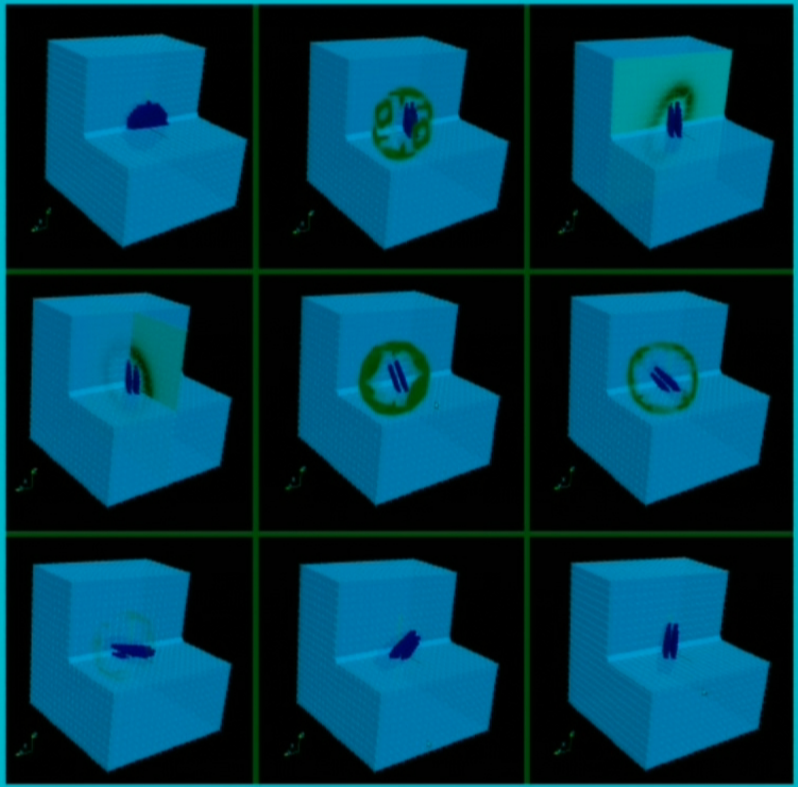
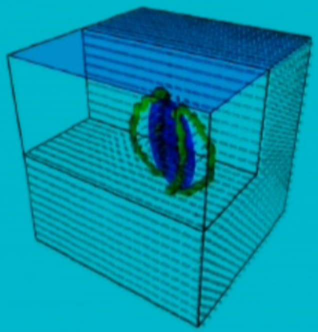
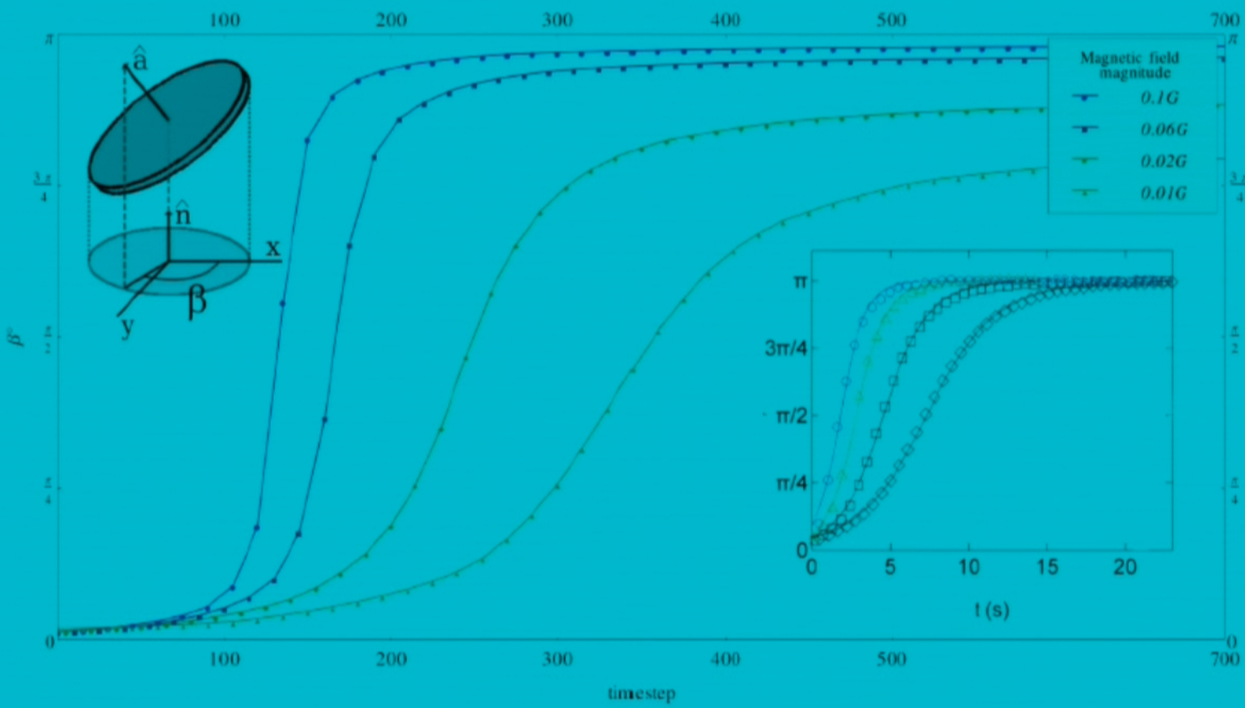
Abstract: We simulated Ni disc immersed in a liquid crystal using a lattice Boltzmann algorithm for liquid crystals. In the absence of external torques discs with homeotropic anchoring align with their surface normal parallel to the director of the nematic liquid crystal. In the presence of a weak magnetic field (<10G) the disc will rotate to equilibrate the magnetic torque and the elastic torque due to the distortion of the nematic director. When the magnetic field rotates the disc so that the angle between normal to the surface of the disc and director of the liquid crystal becomes greater than the disc goes through the transition in which . The analysis of this behavior was performed.

Defect picture





Disk's flip velocity



Dynamics of the magnetic disc in nematic liquid crystal under the action of magnetic field

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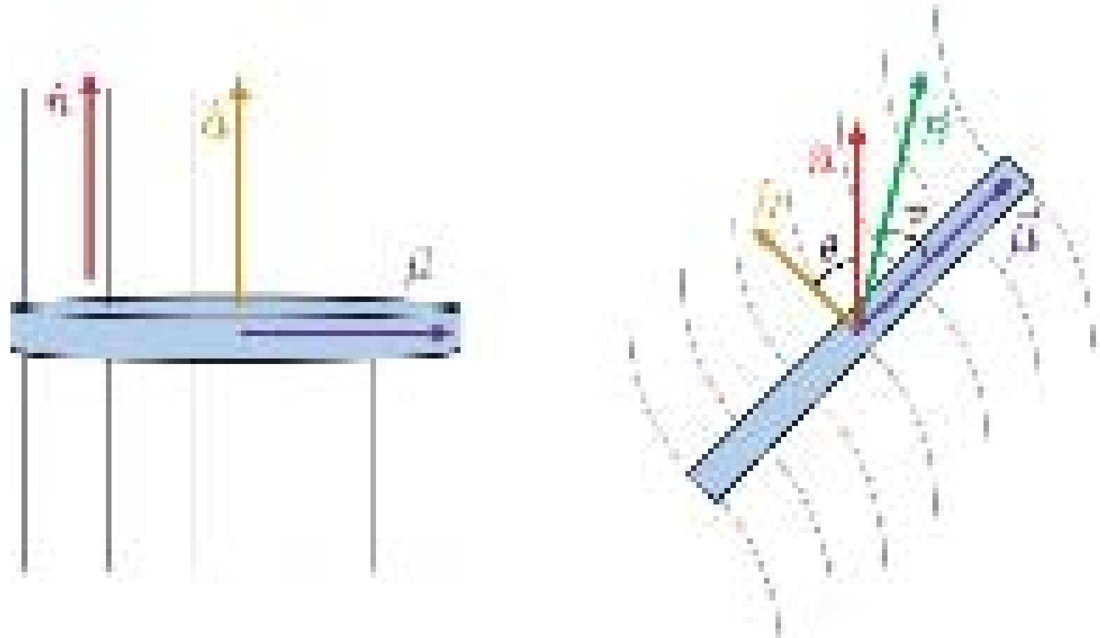
December 5, 2013

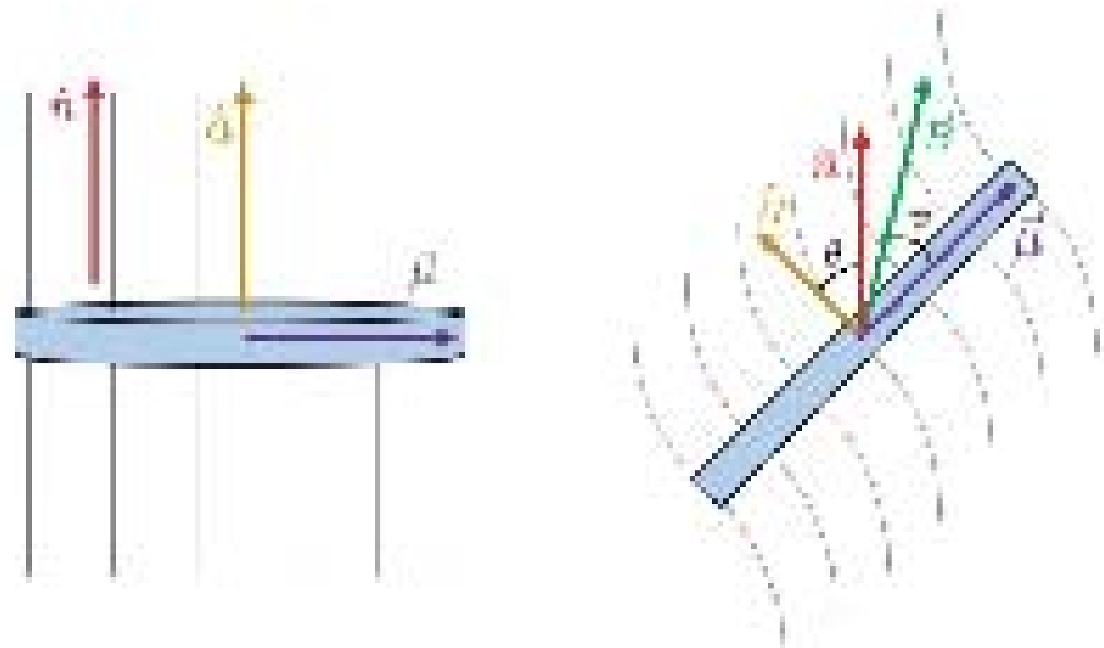
The problem



Elastic and hydrodynamic torques on a colloidal disk within a nematic liquid crystal, R. Leheny et al.

- No external forces

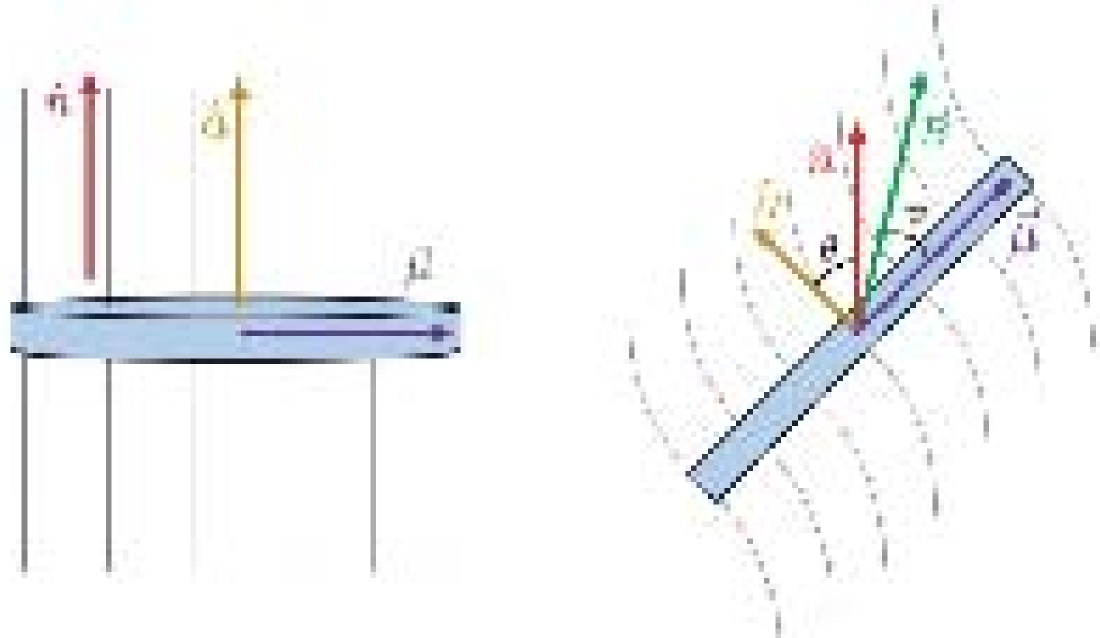
The problem



Elastic and hydrodynamic torques on a colloidal disk within a nematic liquid crystal, R. Leheny et al.

- No external forces
- Back to equilibrium

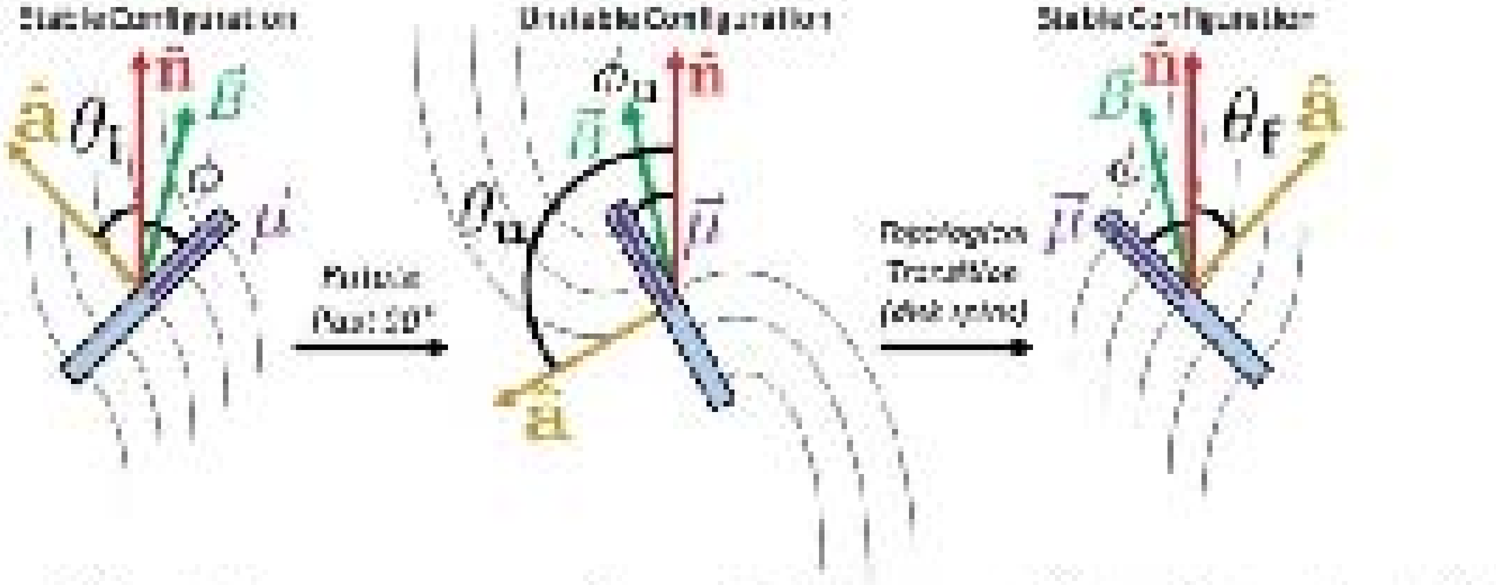
The problem



Elastic and hydrodynamic torques on a colloidal disk within a nematic liquid crystal, R. Lehany et al.

- No external forces
- Back to equilibrium
- Flip

The problem

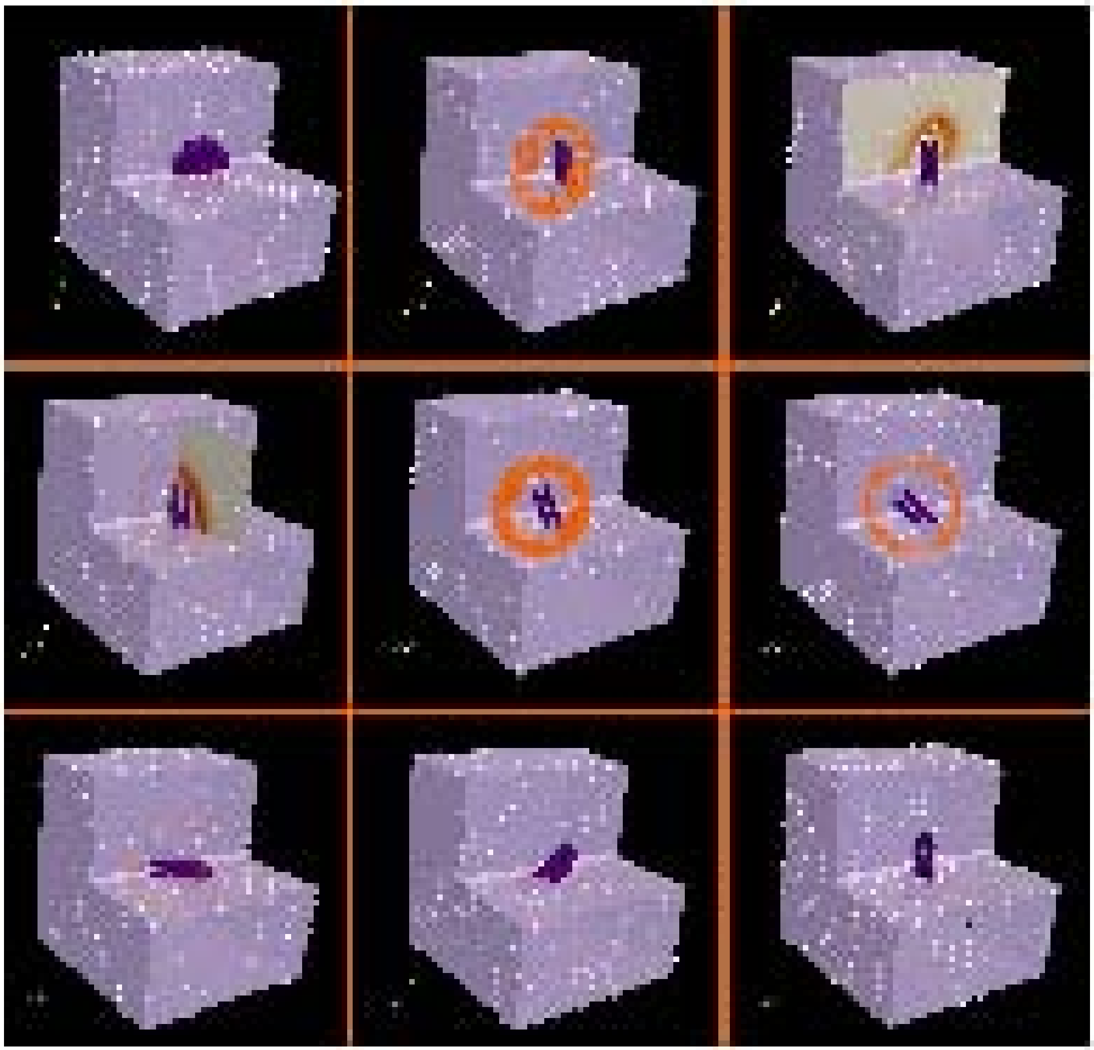


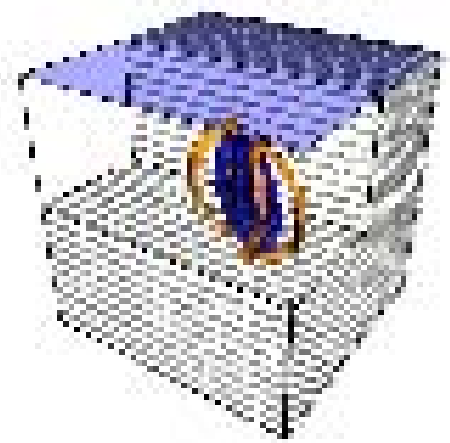
$\theta_i < \frac{\pi}{2}$ $\theta_u > \frac{\pi}{2}$ $\theta_u > \frac{\pi}{2}$ $\theta_f < \frac{\pi}{2}$

Elastic and hydrodynamic torques on a colloidal disk within a nematic liquid crystal, R. Lehany et al.

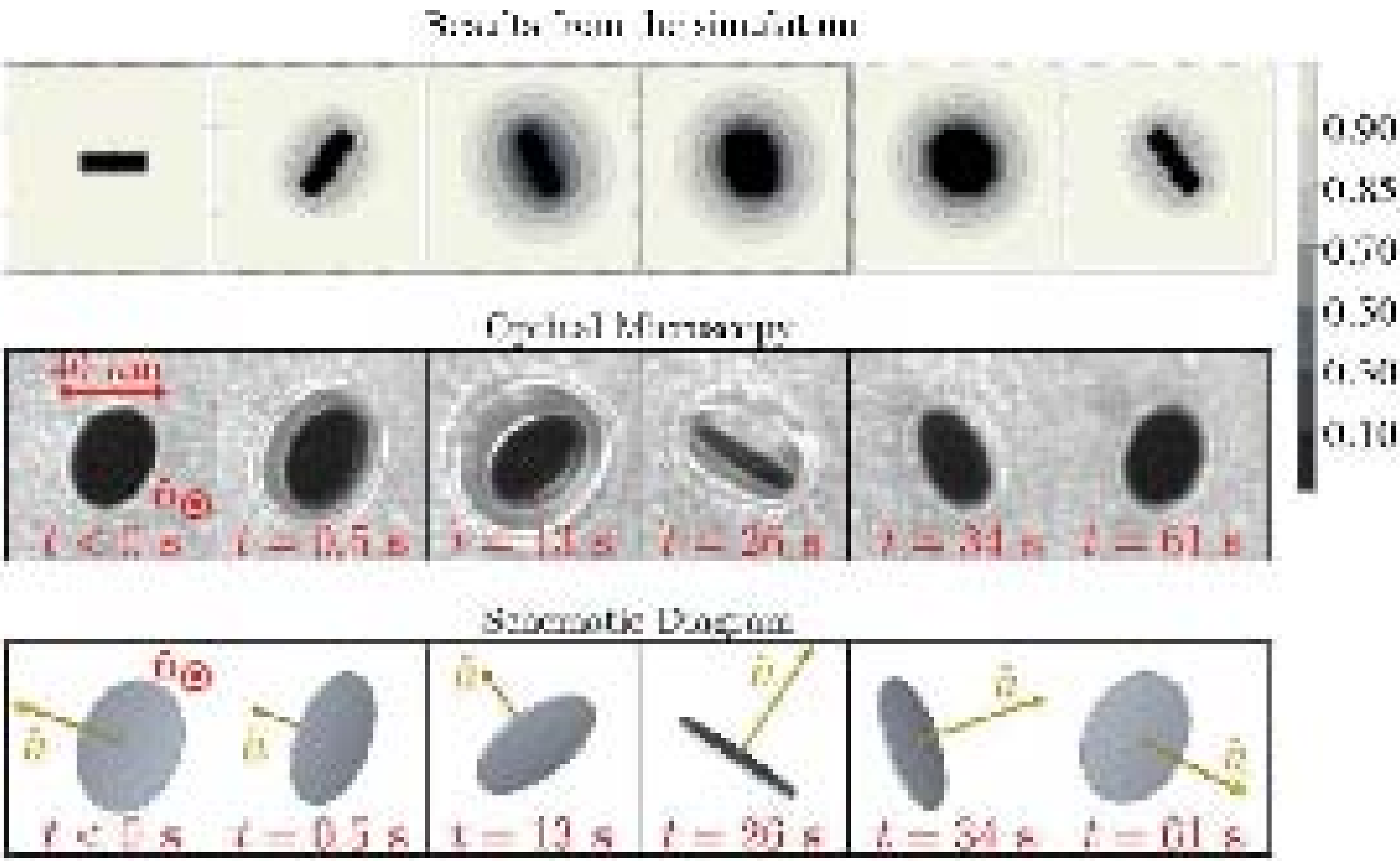
- No external forces
- Back to equilibrium
- Flip

Defect picture



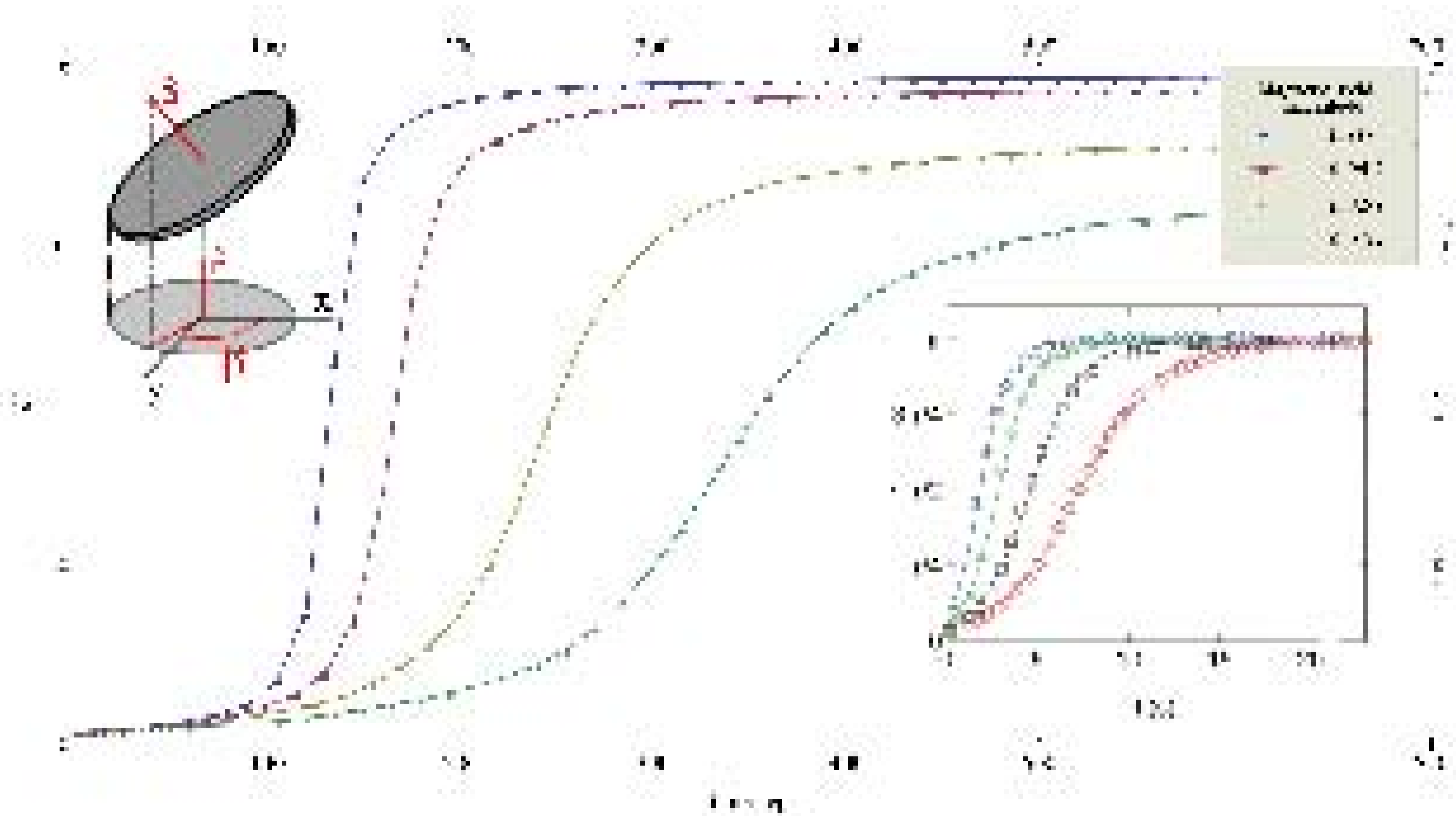


Light transmission



"Elastic and hydrodynamic torques on a colloidal disk within a nematic liquid crystal",
J. Rovner , D.Borgnia, D. Reich, R. Leheny, Physical Review E Stat. Nonlin. Soft. Matter. Phys. (2012)

Disk's flip velocity



References

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Thank you!

Equations of motion (2)

1) Continuity equation

$$(\partial_t \rho + \partial_\alpha \rho u_\alpha) = 0$$

2) Navier - Stokes equation

$$\rho \partial_t u_\alpha + \rho u_\beta \partial_\beta u_\alpha = \partial_\beta \tau_{\alpha\beta} + \partial_\beta \sigma_{\alpha\beta} + \frac{\rho \tau_f}{3}(\partial_\beta (\delta_{\alpha\beta} - 3\partial_\rho P_0)\partial_\gamma u_\gamma + \partial_\alpha u_\beta + \partial_\beta u_\alpha)$$

where $\sigma_{\alpha\beta}$ is symmetric contribution to the stress tensor

$$\sigma_{\alpha\beta} = -P_0 \delta_{\alpha\beta} - \xi H_{\alpha\gamma}(Q_{\gamma\beta} + \frac{1}{3}\delta_{\gamma\beta}) - \xi (Q_{\alpha\gamma} + \frac{1}{3}\delta_{\alpha\gamma}) H_{\gamma\beta} + 2\xi (Q_{\alpha\beta} + \frac{1}{3}\delta_{\alpha\beta}) Q_{\gamma\epsilon} H_{\gamma\epsilon} - \partial_\beta Q_{\gamma\nu} \frac{\delta F}{\delta \partial_\alpha Q_{\gamma\nu}}$$

and $\tau_{\alpha\beta} = Q_{\alpha\gamma} H_{\gamma\beta} - H_{\alpha\gamma} Q_{\gamma\beta}$ is antisymmetric contribution, $P_0 = \rho T - \frac{1}{2} k (\nabla Q)^2$ is pressure.

Back to Equations of motion

Equations of motion (3)

3) Tensor order parameter evaluated by

$$(\partial_t + u \cdot \nabla) Q - S(W, Q) = \Gamma H,$$

where Γ is collective rotational diffusion constant,

$$S(W, Q) = (\xi D + \Omega)(Q + \frac{1}{3} I) + (Q + \frac{1}{3} I)(\xi D - \Omega) - 2\xi (Q + \frac{1}{3} I)\, Tr(QW)$$

where D and Ω are symmetric and antisymmetric parts of $W_{\alpha\beta} = \partial_\beta u_\alpha$ respectfully:

$$D = \frac{1}{2}(W + W^T), \Omega = \frac{1}{2}(W - W^T),$$

and $H = -\frac{\delta F}{\delta Q} + \frac{1}{3} I\, Tr(\frac{\delta F}{\delta Q})$ is molecular field.

Back to Evaluation

Evaluation (2)

$$f_i(x + e_i \Delta t, t + \Delta t) = f_i(x, t) + \frac{\Delta t}{2}[C_{f_i}(x, t, f_i) + C_{f_i}(x + e_i \Delta t, t + \Delta t, \{f_i^*\})]$$

$$G_i(x + e_i \Delta t, t + \Delta t) = G_i(x, t) + \frac{\Delta t}{2}[C_{G_i}(x, t, \{G_i\}) + C_{G_i}(x + e_i \Delta t, t + \Delta t, \{G_i^*\})]$$

Collision operators

$$C_{f_i}(x, t, f_i) = -\frac{1}{\tau_f}(f_i(x, t) - f_i^{eq}(x, t, \{f_i\})) + \rho_i(x, t, \{f_i\})$$

$$C_{G_i}(x, t, f_i) = -\frac{1}{\tau_G}(G_i(x, t) - G_i^{eq}(x, t, \{G_i\})) + M_i(x, t, \{G_i\})$$

Evaluation (3)

Constraints

$$\sum_i f_i^{eq} = \rho, \sum_i f_i^{eq} e_{i\alpha} = \rho u_\alpha, \sum_i f_i^{eq} e_{i\alpha} e_{i\beta} = -\sigma_{\alpha\beta} + \rho u_\alpha u_\beta,$$

$$\sum_i \rho_i = 0, \sum_i \rho_i e_{i\alpha} = \partial_\beta \tau_{\alpha\beta}, \sum_i \rho_i e_{i\alpha} e_{i\beta} = 0,$$

$$\sum_i G_i^{eq} = Q, \sum_i G_i^{eq} e_{i\alpha} = Q u_\alpha, \sum_i G_i^{eq} e_{i\alpha} e_{i\beta} = Q u_\alpha u_\beta,$$

$$\sum_i M_i = \Gamma H(Q) + S(W, Q), \sum_i M_i e_{i\alpha} = (\sum_i M_i) u_\alpha$$

Back to Evaluation