Bari Theory Xmas Workshop 2015

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Cholesteric liquid crystal droplets under electric fields

di
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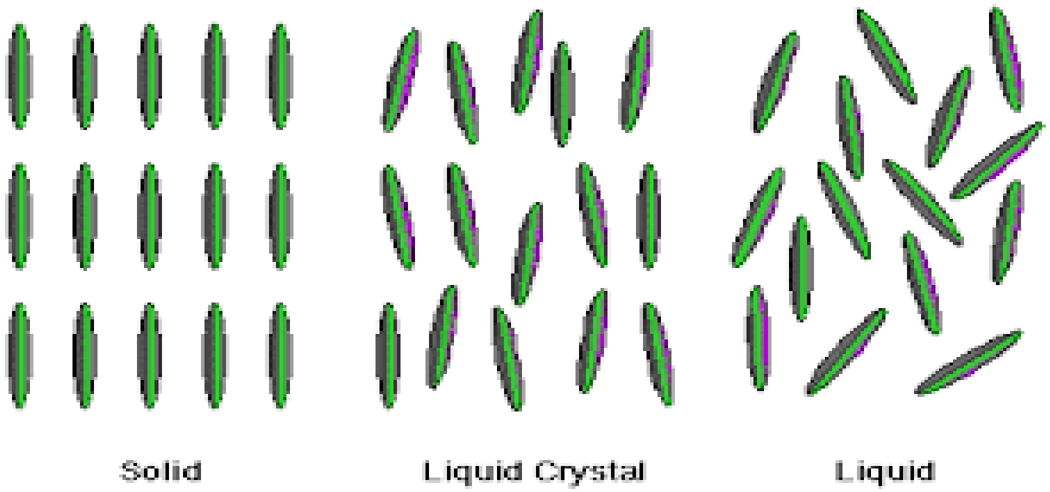
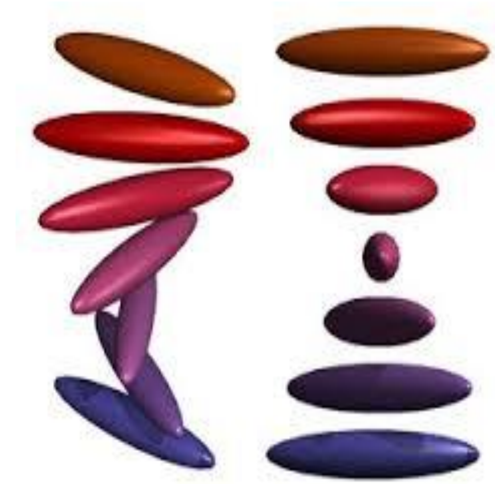
What are cholesteric liquid crystals?





- Liquid crystals are an intermediate state of matter between solids and liquids -> they possess a long range orientational order and they also flow;
- The degree of order is quantified by the director, |**n**|=1 and **n**->-**n** invariant!
- Tensorial order parameter, 2nd rank , symmetric, traceless with 5 independent components -> $Q_{\alpha\beta} = q\left(n_\alpha n_\beta - \frac{1}{3}\delta_{\alpha\beta}\right)$, $0<q<1$, α e $\beta = x,y,z$
- Cholesteric liquid crystals or chiral nematic are an interesting mesophase of liquid crystals where molecules exhibit a helical arrangement with a certain pitch;

Dynamical equations

- *Continuity equation:*

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

- *Navier-Stokes equation:*

$$n(\partial_t + u_\beta \partial_\beta) u_\alpha = \partial_\beta \left(\prod_{\alpha\beta}\right) + \eta \partial_\beta (\partial_\alpha u_\beta + \partial_\beta u_\alpha)$$

- *Beris-Edwards equation:*

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

$$\boldsymbol{S}(\boldsymbol{W}, \boldsymbol{D}) = (\xi \boldsymbol{D} + \boldsymbol{\omega})\left(\boldsymbol{Q} + \frac{\boldsymbol{I}}{3}\right) + \left(\boldsymbol{Q} + \frac{\boldsymbol{I}}{3}\right)(\xi \boldsymbol{D} - \boldsymbol{\omega}) + -2\xi \left(\boldsymbol{Q} + \frac{\boldsymbol{I}}{3}\right) Tr(\boldsymbol{QW}),$$

$$\boldsymbol{D} = \frac{(\boldsymbol{W} + \boldsymbol{W}^T)}{2}, \boldsymbol{\omega} = \frac{(\boldsymbol{W} - \boldsymbol{W}^T)}{2}, W_{\alpha\beta} = \partial_\alpha u_\beta$$

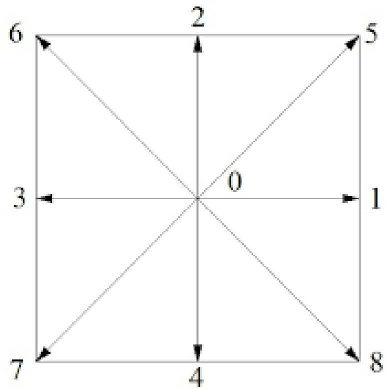
$$\boldsymbol{H} = -\frac{\partial \mathfrak{F}}{\partial \boldsymbol{Q}} + \frac{\boldsymbol{I}}{3} Tr\left(\frac{\partial \mathfrak{F}}{\partial \boldsymbol{Q}}\right)$$

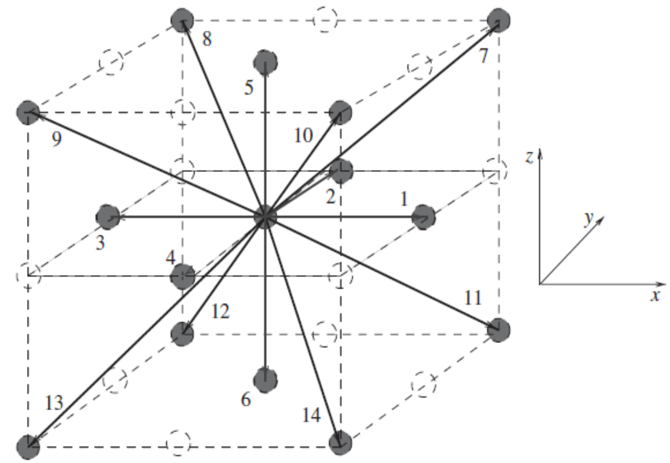
- *Cahn-Hilliard equation:*

$$\partial_t \phi + \partial_\alpha (u_\alpha \phi) = D \nabla^2 \mu$$

Hybrid Lattice Boltzmann method

- Discretization of the space with a lattice-> ***D2Q9*** *and* ***D3Q15***





- In the continuum limit *the continuity* and *Navier Stokes equations* are obtained!!!
- Why hybrid??? -> This method solves the *continuity* and *Navier-Stokes equations* in the standard way and the *Beris-Edward* and the *Cahn-Hilliard equations* with a finite-difference method.

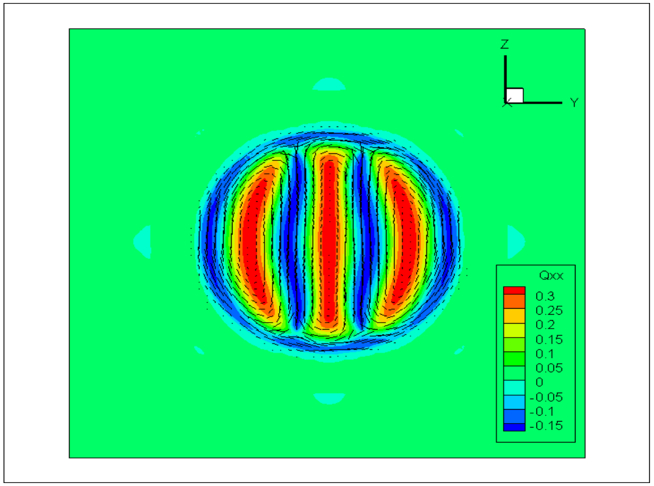
Influence of the electric fields

- If a DC electric field is switched on the director moves parallel to the field if $\varepsilon>0$ and ortogonal if $\varepsilon<0$. (*P.G. de Gennes and J. Prost, The Physics of Liquid Crystals, Clarendon Press, 2° edn, 1993; S. Chandrasekhar, Liquid Crystals, Cambridge University Press, (1980), A.N. Beris, B. J. Edwards, Thermodynamics of Flowing System, Oxford University Press, Oxford (1994)*)

- *Lehmann rotation (1901)* when the cholesteric droplet is under a temperature gradient -> recent works (*Physical Review E* ***68***, *031708 (2003), Physical Review E* ***89***, *022509 (2014), Optics Express 6877 2008, Phil. Trans. R. Soc. A (2006)* ***364***, *2789-2805*).

Simulations and results

$R=32$
$p_0=32$
$\omega=0.001$



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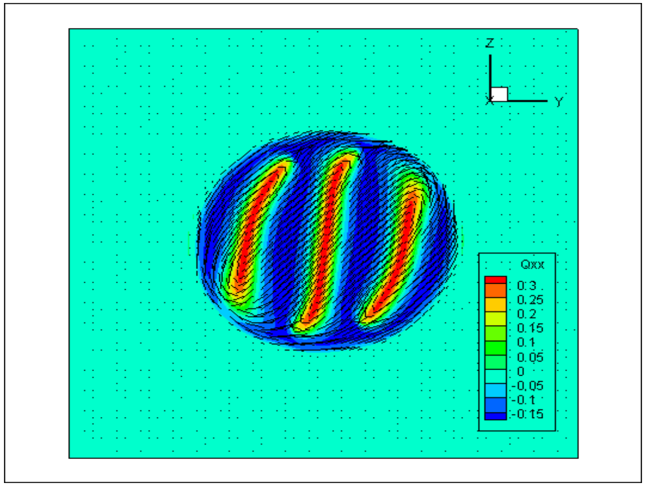

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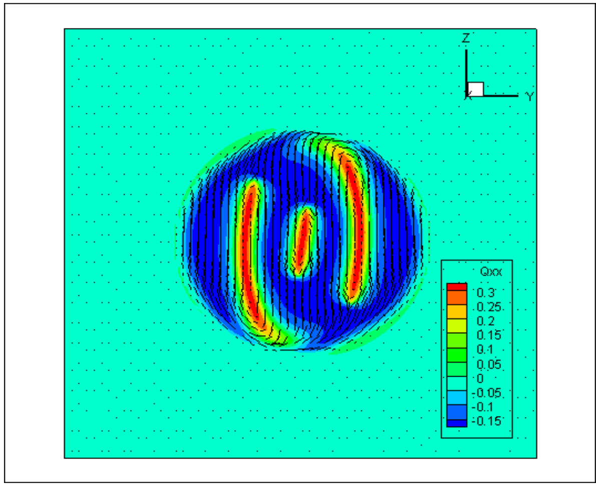

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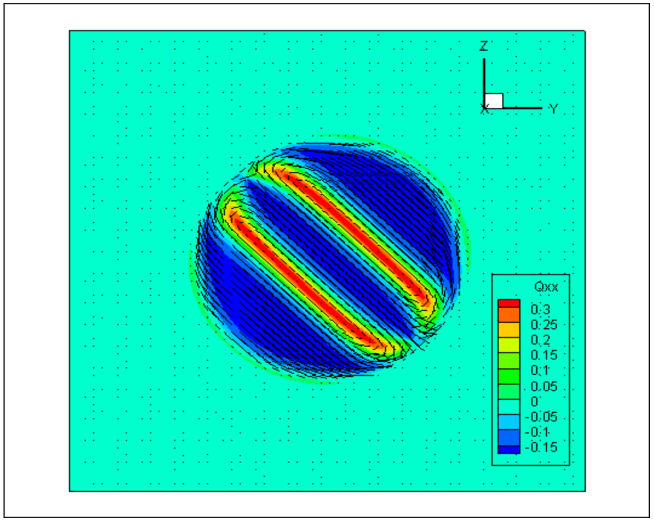

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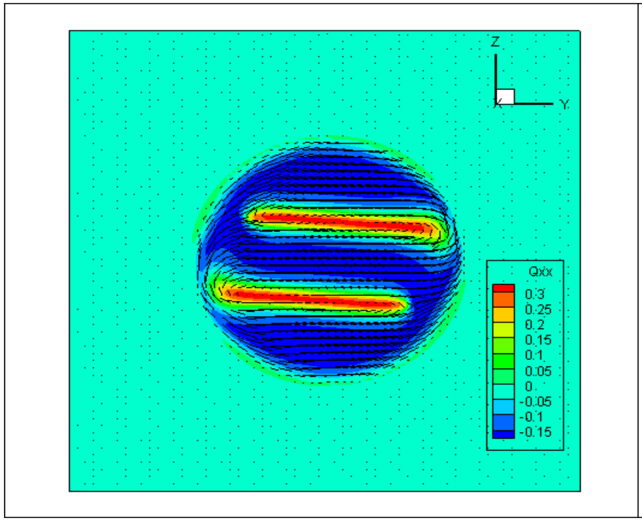

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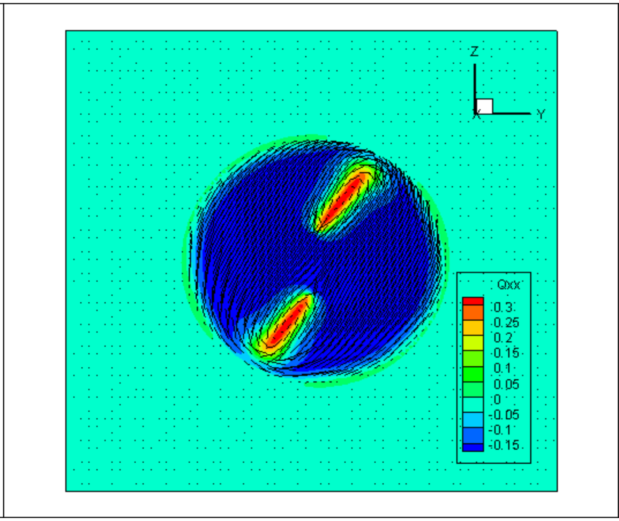

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