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COLLECTIVE FLUCTUATIONS IN A VERY THIN HYBRID NEMATIC FILM AND EVANESCENT LIGHT SCATTERING

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S. Zumer

INTRODUCTION



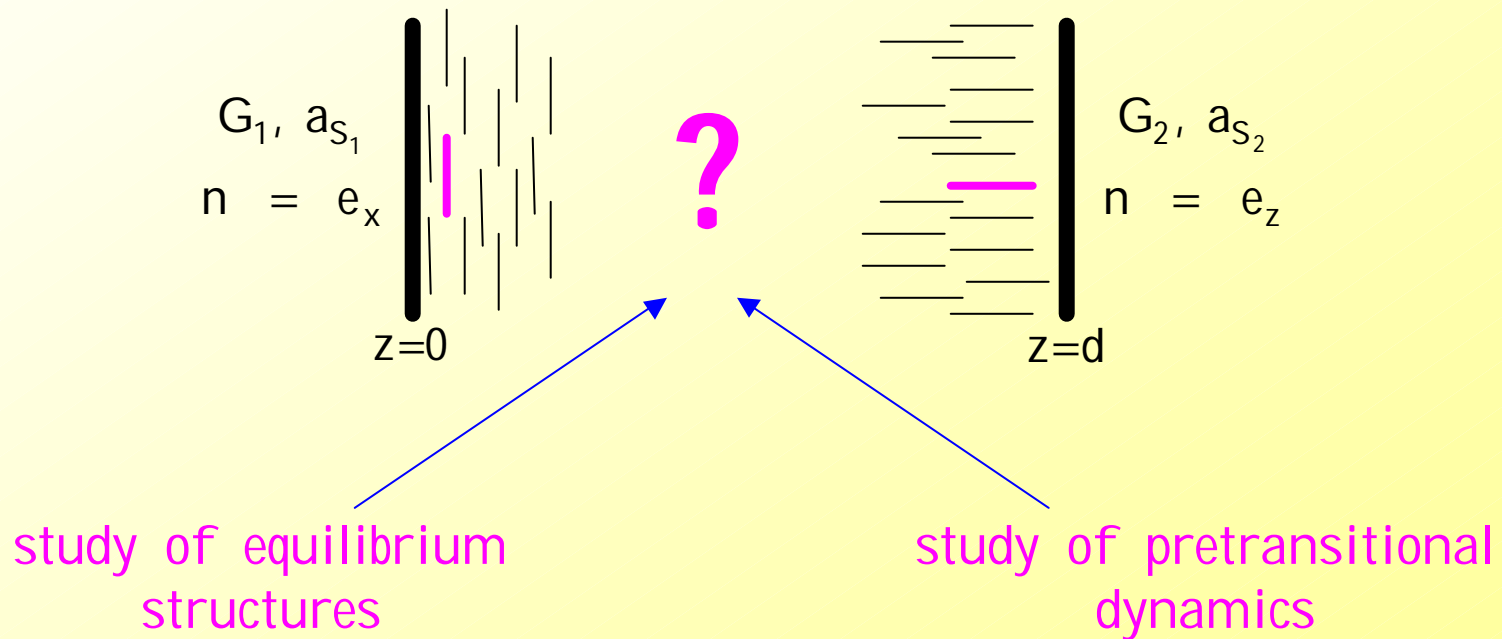
hybrid nematic film



- ▶ confined nematic liquid crystal
- ▶ frustrated boundary conditions

MODEL SYSTEM

- planar geometry
- confining substrates
 - ▶ mutually perpendicular easy axes
 - ▶ induce uniaxial nematic order
 - ▶ arbitrary anchoring



G. Barbero and R. Barberi, J. Phys. **44**, 609 (1983).
P. Palffy-Muhoray *et al.*, Liq. Cryst. **16**, 713 (1994).

A. Šarlah and S. Zumer, PRE **60**, 1821 (1999).

THEORETICAL DESCRIPTION

- Landau-de Gennes phenomenological description
(one-elastic constant approximation)

$$f = \frac{1}{2} A(T - T^*) \operatorname{tr} Q^2 - \frac{1}{3} B \operatorname{tr} Q^3 + \frac{1}{4} C (\operatorname{tr} Q^2)^2 + \frac{1}{2} L \nabla Q : \nabla Q$$

homogeneous part

elastic part

- substrate-liquid crystal interaction is modeled by

$$f_s = \frac{1}{2} G_{1,2} \operatorname{tr}(Q - Q_{S_{1,2}})^2 \begin{cases} \mathbf{d}(z) \\ \mathbf{d}(z - d) \end{cases}$$

boundary conditions

THEORETICAL DESCRIPTION

general elastic distortion free energy contribution
(in tensorial Landau-de Gennes picture)

$$f_{\text{elastic}} = \underbrace{\frac{1}{2} L_1 \partial_i Q_{jk} \partial_i Q_{jk}} + \underbrace{\frac{1}{2} L_2 \partial_j Q_{ij} \partial_k Q_{ik}} + \frac{1}{2} L_3 \partial_k Q_{ij} \partial_j Q_{ik}$$

one-elastic constant
approximation



$$K_1 = K_2 = K_3$$

(in the Frank elastic theory)

nonzero when Q depends on more
than one coordinate



spontaneously modulated structures

O.D. Lavrentovich and V. Pergamenschik,
PRL **73**, 979 (1994).

THEORETICAL DESCRIPTION

DYNAMIC EQUATION

$$-\Gamma \frac{\partial Q}{\partial t} = \frac{\partial f}{\partial Q} - \nabla \cdot \frac{\partial f}{\partial \nabla Q}$$

relaxation

equilibrium condition

$$Q(r, t) = A(r) + B(r, t)$$

mean-field
equilibrium

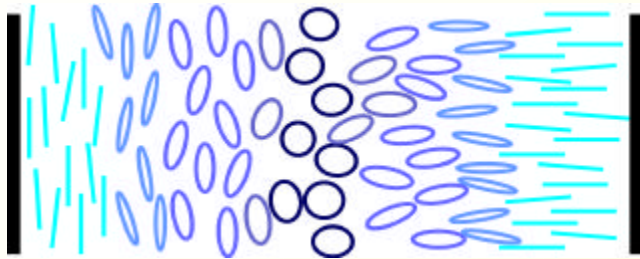
small fluctuations
around equilibrium

▶ harmonic approximation

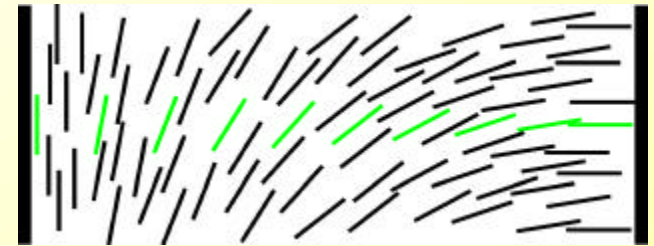
▶ exponential decay - \mathbf{n}_i

▶ $B(r, t) = \sum_{i=-2}^2 b_i(r, t) T_i$

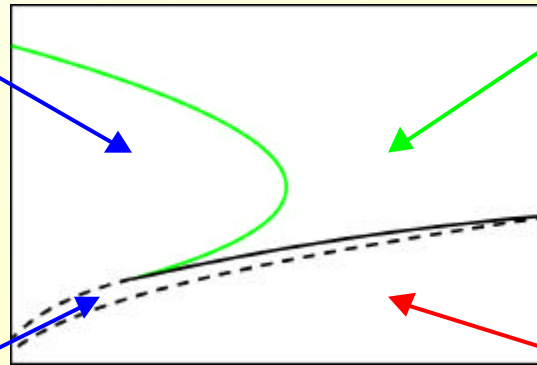
EQUILIBRIUM STRUCTURES



biaxial structure
(eigenvalue exchange)



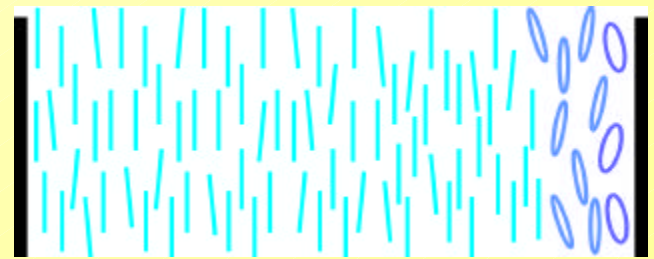
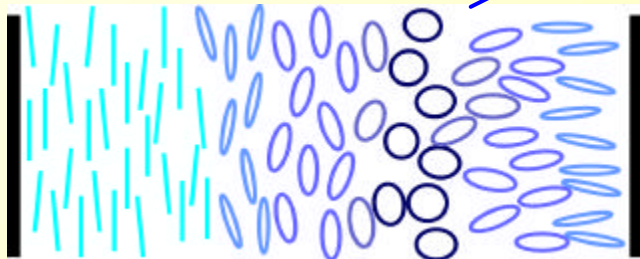
bent director
structure



$$d_c = |\mathbf{L}_2 - \mathbf{L}_1|$$

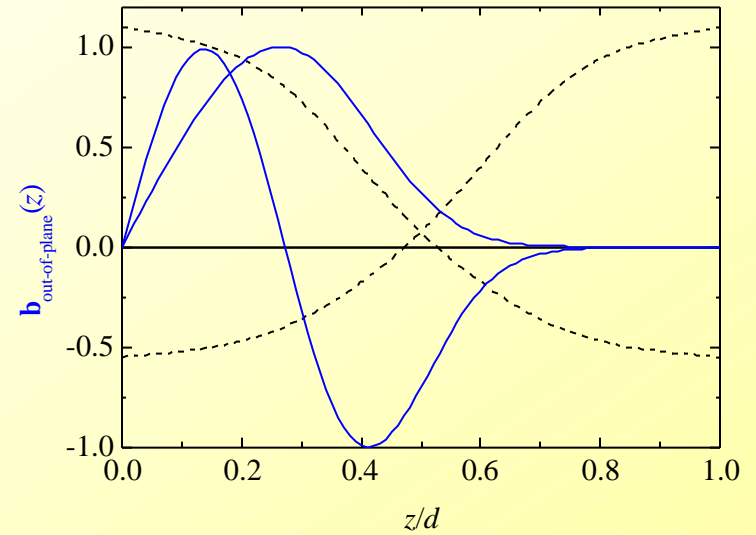
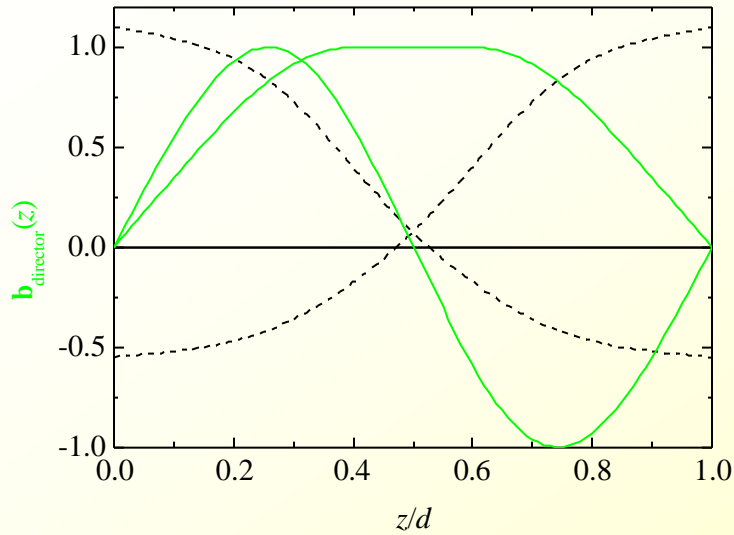
$$(\mathbf{L}_i = \mathbf{L} / G_i)$$

uniform director
structure



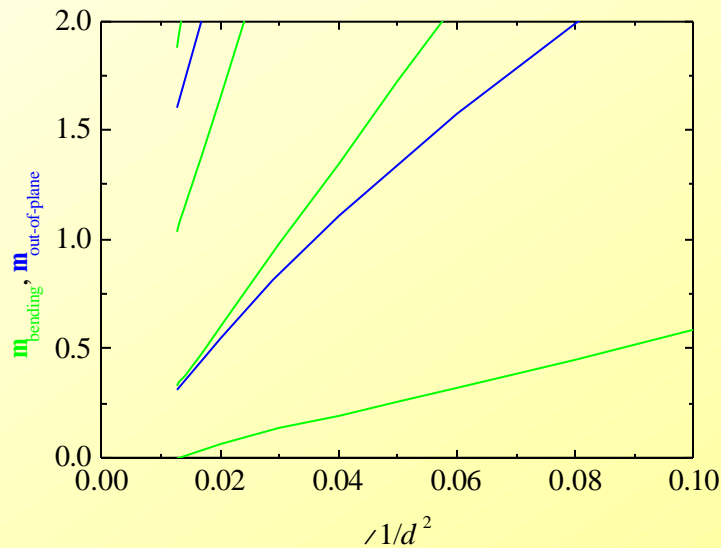
DIRECTOR FLUCTUATIONS

biaxial structure \rightarrow bent-director structure



bending director modes

- ▶ eigenmodes spread over the whole film
- ▶ critical slowdown of the lowest mode

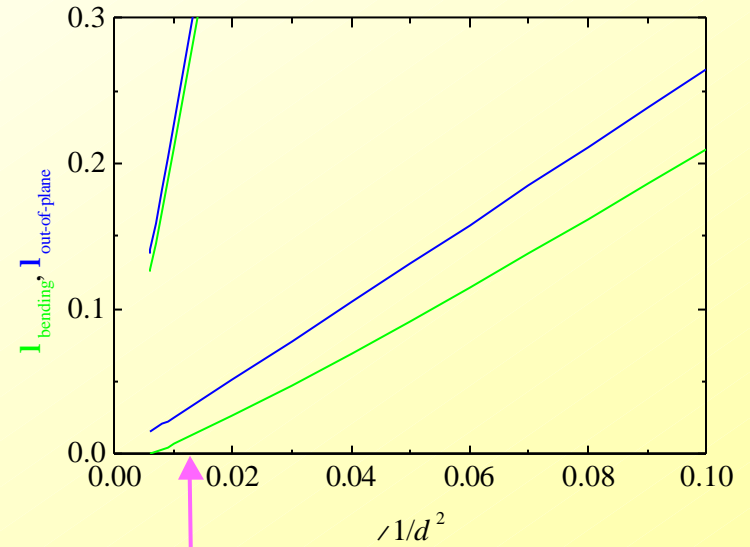
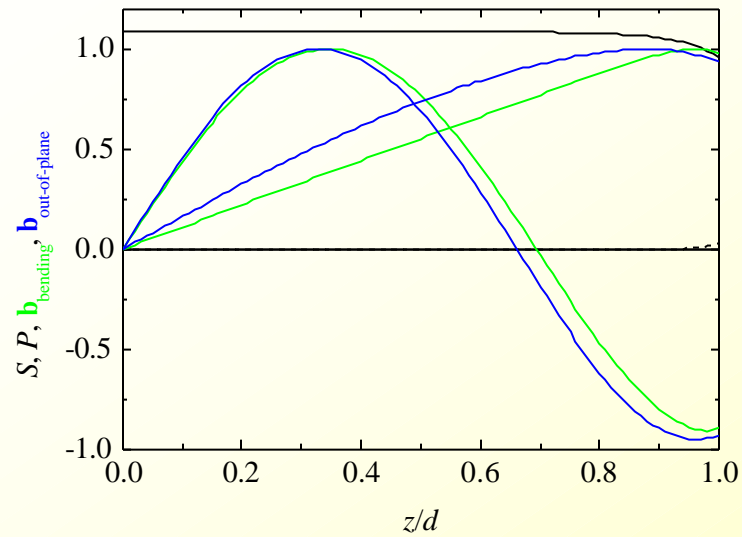


out-of-plane director modes

- ▶ localized few lowest modes
- ▶ non-critical, degenerated spectra

DIRECTOR FLUCTUATIONS

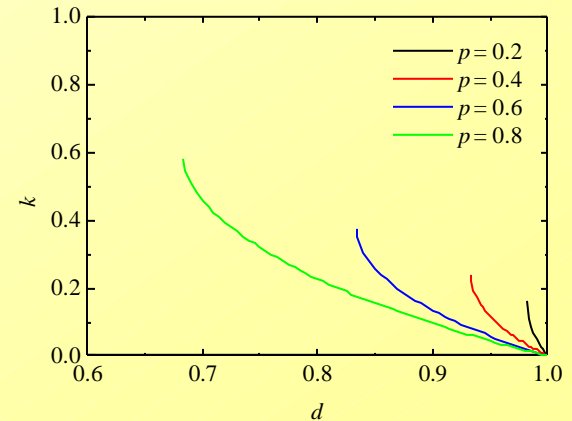
uniform director structure \rightarrow bent-director structure



bending director modes

- ▶ eigenmodes spread over the whole film
- ▶ critical slowdown

spontaneously modulated structures



LIGHT SCATTERING

inhomogeneities of the tensor order parameter

fluctuations of the tensor order parameter

inhomogeneities of the dielectric constant tensor

light scattering

$$\underline{\epsilon} \propto \epsilon_a Q(r, t) + \epsilon I$$

amplitude of the scattered light

$$E_s \propto \int dr^3 E_e(r, t) e^{-ik_s \cdot r} f \cdot \underline{\epsilon}(r, t) \cdot i$$

autocorrelation function

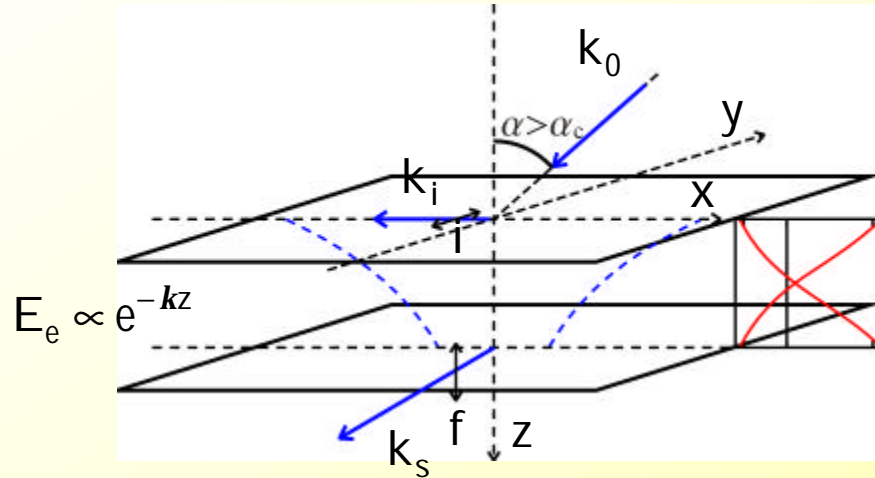
$$G(t)_{\text{dyn}} = \langle E_s(0) E_s^*(t) \rangle_{\text{dyn}} \propto \sum_n \frac{R_n^2}{m_{n,q}} e^{-m_{n,q} t}$$

$$R_n = \int dz \mathbf{b}_n(z) e^{-kz}$$

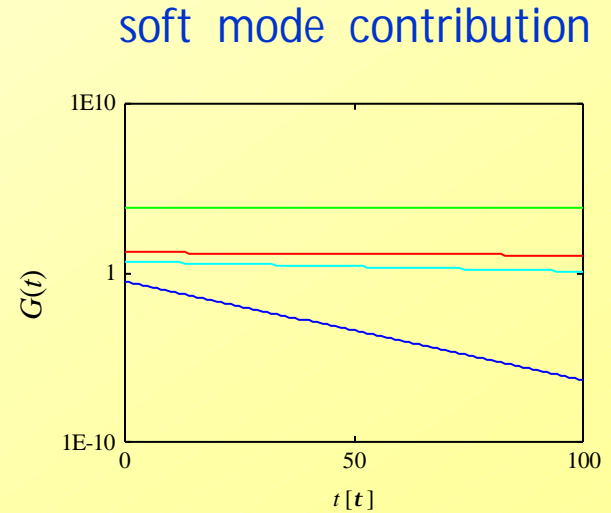
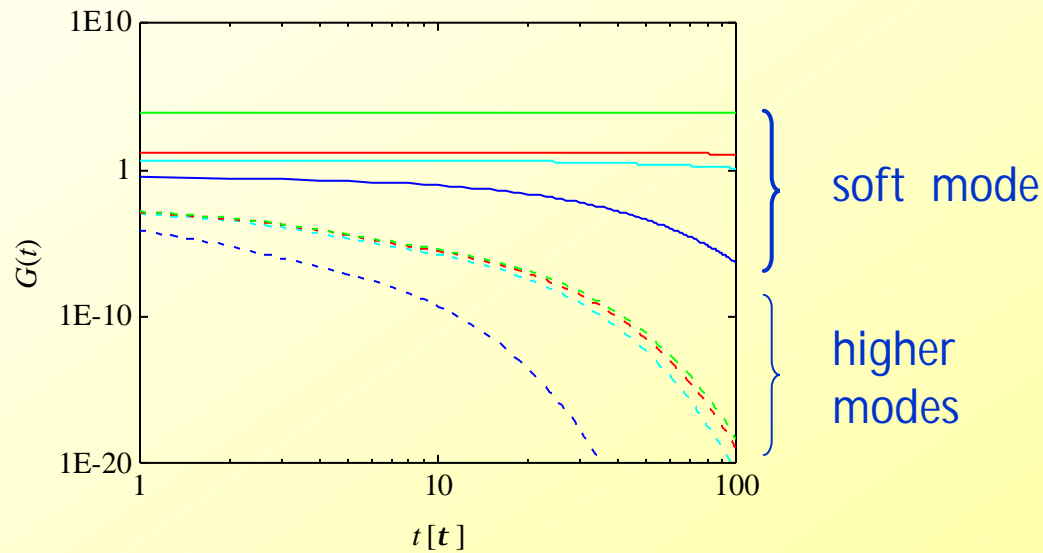
evanescent light scattering

- ▶ total reflection of the incoming light
- ▶ $q = |k_i - k_f|$, $k_i = k_0 \sin a$
- ▶ $\mathbf{k} = k_0 \sqrt{\sin^2 a - \sin^2 a_c}$

EXPERIMENTAL SETUP FOR EVANESCENT LIGHT SCATTERING



thin hybrid cell



SUMMARY

- in a hybrid geometry variety of equilibrium structures can be obtained
 - ▶ biaxial structure
 - * thin films $d < 200 \text{ nm}$
 - * strong anchorings $G_1 \approx G_2 > 10^{-4} \text{ J/m}^2$
 - * close to bulk nematic-isotropic phase transition temperature
 - ▶ uniform director structure
 - * thin films
 - * unequal anchorings $d < L |1/G_1 - 1/G_2|$
 - ▶ bent-director structure
 - * thicker films
 - ▶ modulated structures
- soft bending director modes \longrightarrow structural transitions
- evanescent light scattering

deep in the
nematic phase