Annihilation of Point Defect Pairs

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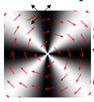
Motivation

Topological defects are found in a broad variety of dynamic physical systems such as anisotropic fluids, quantum systems or even in cosmology. Defect dynamics are of crucial importance, particularly at phase transitions.

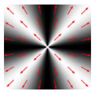
Liquid crystals allow straightforward optical observations, with sample dimensions and time scales in conveniently accessible ranges. Studies in nematics are not easy to interpret because of the three-dimensionality of the problem. Freely suspended smectic-C films are an ideal model to study defect dynamics: they behave as quasi-twodimensional polar nematics.

Topological defects of the c-director

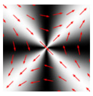
S = topological charge (defect strength)



S= 1
Tangential
$\theta = \varphi \pm \frac{\pi}{2}$



S= 1
radial
$\theta = \varphi$



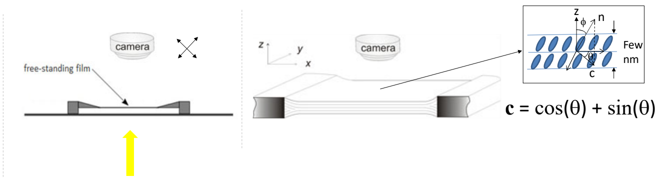
S= - 1
$\theta = -\varphi$

$\varphi = \tan^{-1}(y/x)$ angle in polar coordinates

- What is the consequence of elastic anisotropy?
- What is the actual dynamics of annihilating defect pairs?

Materials and Experimental techniques

Smectic-C freely suspended films:
- Uniformly thick
- Ideal model systems for quasi-two dimensional fluids.
- Anisotropies in the layer plane, (c-director).



c = cos(θ) + sin(θ)

Free-standing film setup

Materials: **Sm-C:** 5-n-octyle-2-[4-(n-hexyloxy)phenyl]pyrimidine **&** 5-n-decyl-2-[4-(n-octyloxy)phenyl]pyrimidine.

Classical model for nematics

Philosophical Magazine, Vol. 86, Nos. 25–26, 1–11 September 2006, 4117–4137

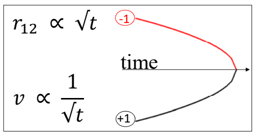
Taylor & Francis

Topological point defects in nematic liquid crystals

M. KLEMAN*† and O. D. LAVRENTOVICH‡

$$V \approx \pm \frac{K}{\gamma\, ln\left(\frac{3{,}6}{Er}\right) r_{12}} \approx \pm \frac{D_1}{r_{12}}$$

Defects of a ± pair approach each other with equal velocity. They meet in their fixed „center of mass".



Model limitations: Neglection of the flow and the elastic anisotropy.

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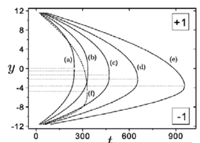
Hydrodynamics of Pair-Annihilating Disclinations in SmC Films

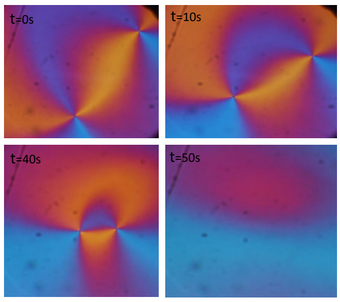
D. Svenšek* and S. Žumer

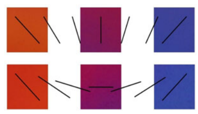


The hydrodynamic flow and the elastic anisotropy both play an important role in defects dynamics.

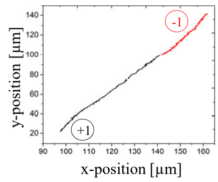
The model is relevant only in the vicinity of the defect cores.

Annihilating defect pair with opposite charges

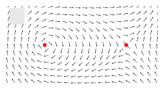


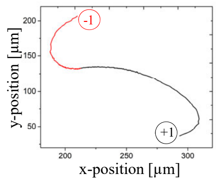


$r_{12} \propto \sqrt{t}$

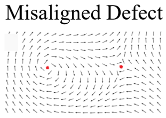


Aligned Defect

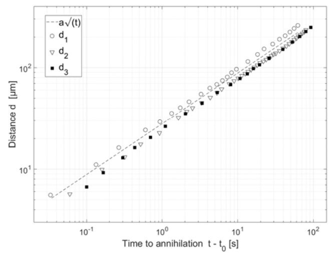


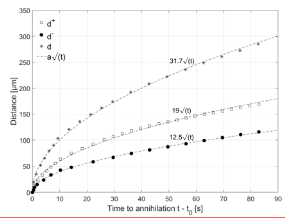


Misaligned Defect



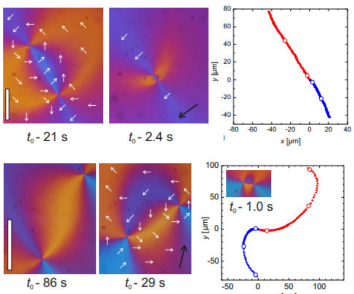
- An asymmetry in the velocity field was found.



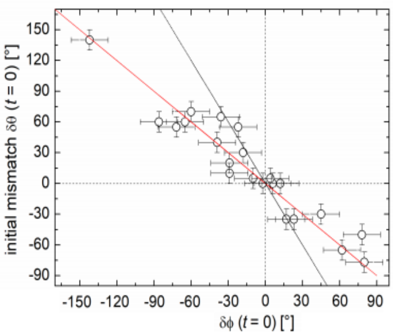


- The orientation of the −1 defect influences the dynamics during the annihilation process.

Orientation of defect pair effects



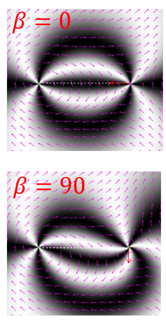
a) Aligned defect pair in homogenous director field. The black arrow is the outer director field orientation. b) Misaligned defect pair. The final annihilation orientation is perpendicular to the outer director field.



- The final defect pair connecting line just before the annihilation is perpendicular to the outer director field. This situation is the lowest energy configuration.
- The mismatch with the outer director field is correlated to the mismatch angle between the pair.

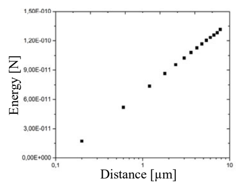
A. Missaoui et al. Phys. *Rev. Lett*. Submitted

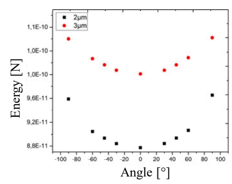
Simulation: Energy landscape



$$F = \frac{1}{2}k(\nabla \phi)^2$$

$$E = -2\pi k s_1 s_2 \ln\left(\frac{r_{12}}{2r_c}\right)$$





- misaligned -1 defect maya rotate to adapt matching, or move on a sigmoidal trajectory.

Summary

- We have developed a technique to create isolated defect pairs with opposite topological charges in SmC films.
- The dynamics is strongly influenced by the orientation of the −1 defect with respect to the connecting axis and the outer field mismatch.
- The generation of flow by defect interactions reduces annihilation times and introduces an asymmetry between the motions of the +1 defect and the -1 defect.