Helfrich-Hurault-like undulations in cholesteric liquid crystals induced by anchoring transitions

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*from M.O. Lavrentovich & L. Tran, Phys. Rev. Research (2020) **2**:023128*

BIRS
October 2022

Liquid crystals - Basics

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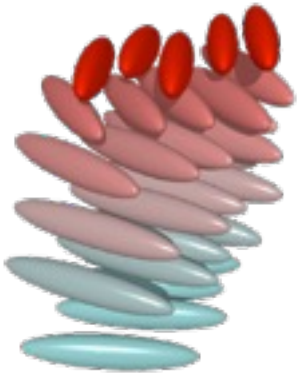
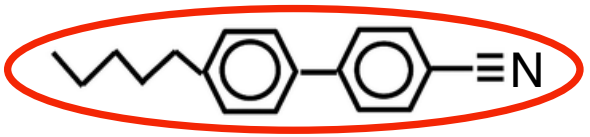
isotropic

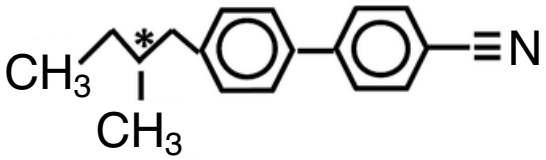
nematic



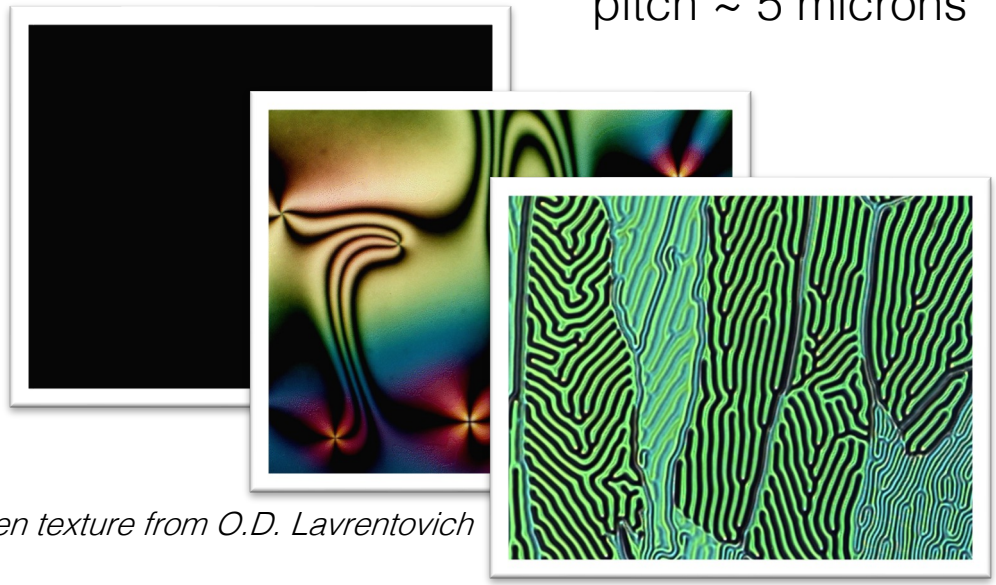
cholesteric



5CB



2.8 wt-% CB15
pitch ~ 5 microns



Schlieren texture from O.D. Lavrentovich

Small molecule liquid crystals in shells

DOI:
10.1103/
PhysRevX.
7.041029

From Guillaume Durey, The Lutetium Project (Youtube)

Shells of cholesterics

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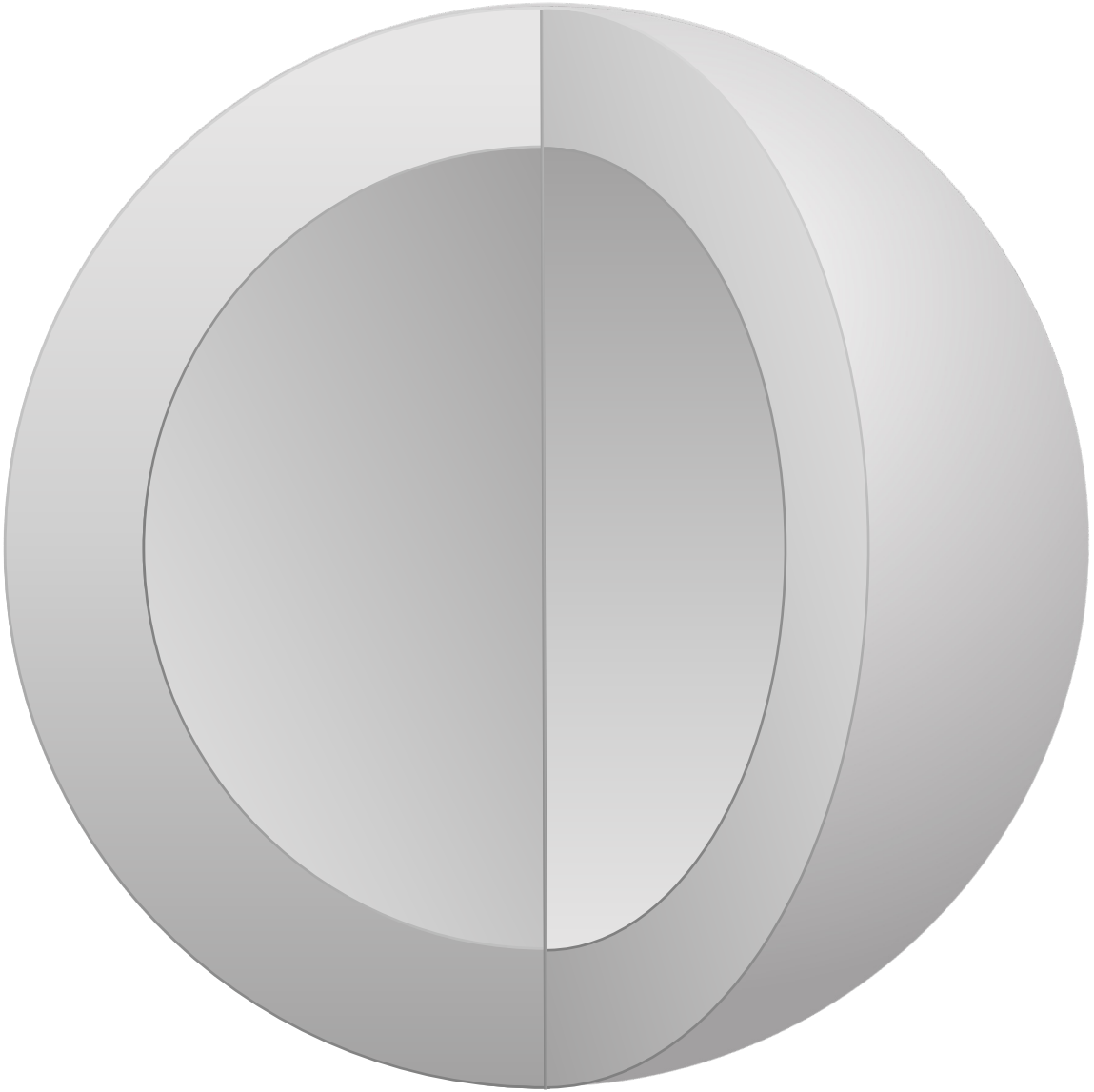

Control bulk structure through surface geometry and anchoring

Cholesteric defects

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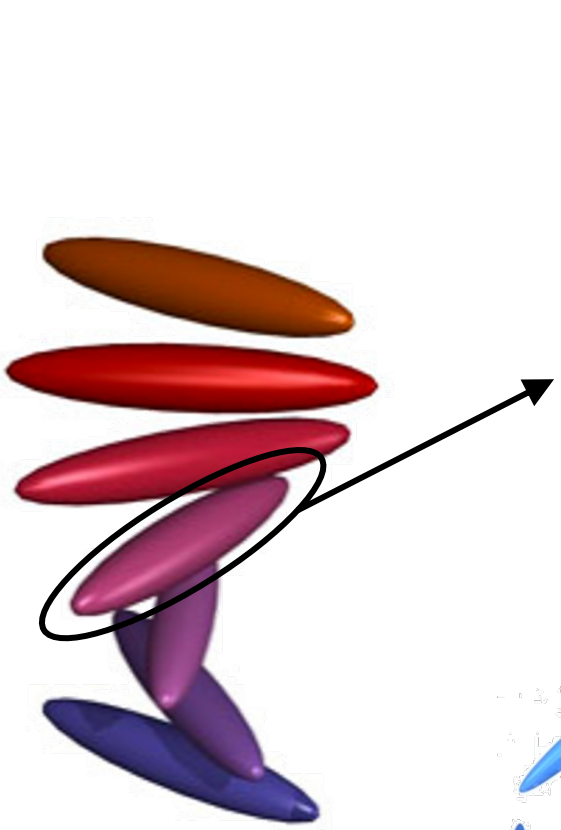
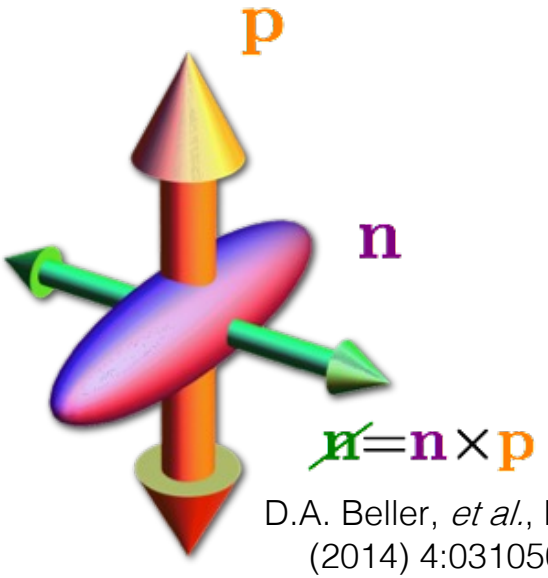
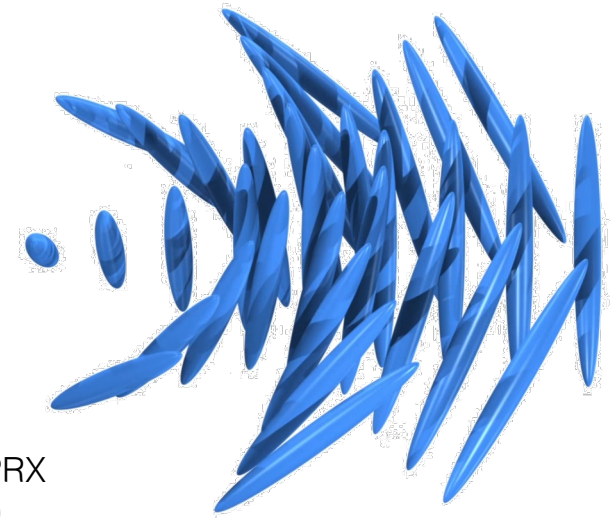
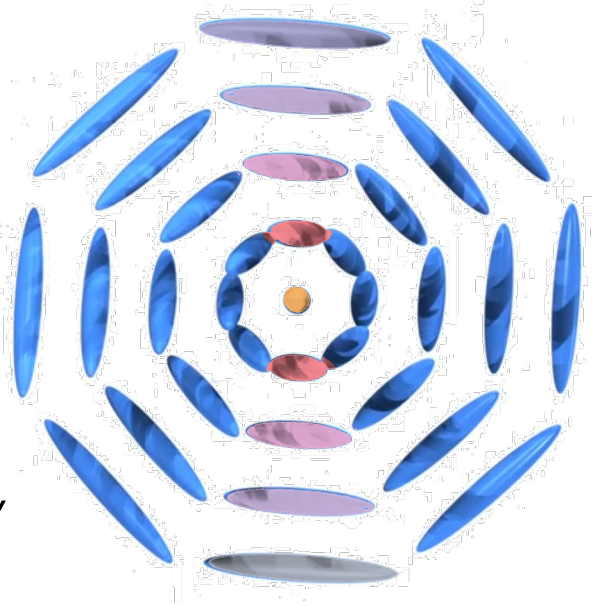




D.A. Beller, *et al.*, PRX (2014) 4:031050



side view



top view

no defect in director, but a defect in the pitch

from H. Yoshida's "Structure of Blue Phase I Liquid Crystal" video

Surface anchoring and geometry

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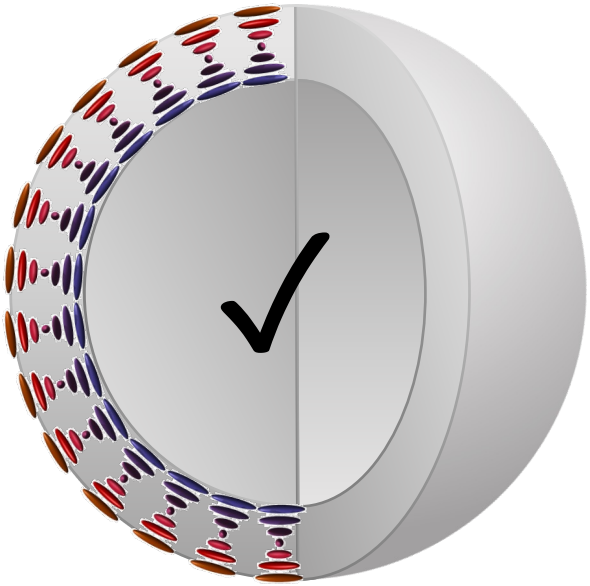
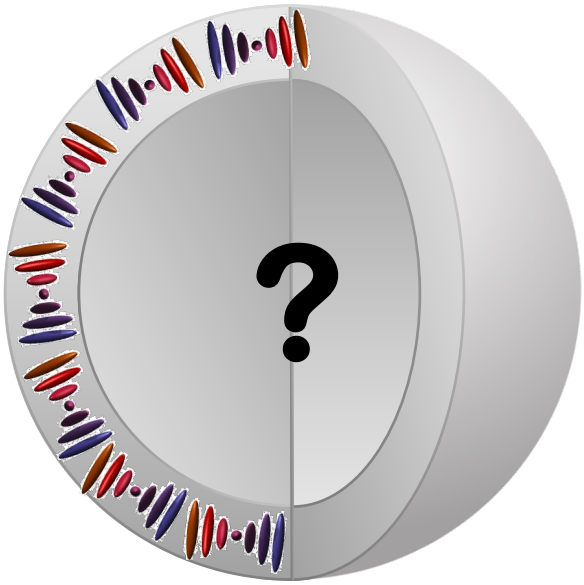
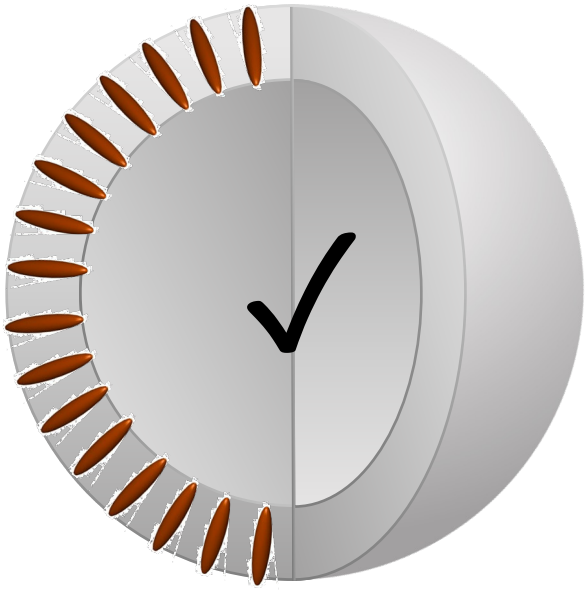


planar anchoring



weak perpendicular anchoring



strong perpendicular anchoring

Ordering stripes in simulations

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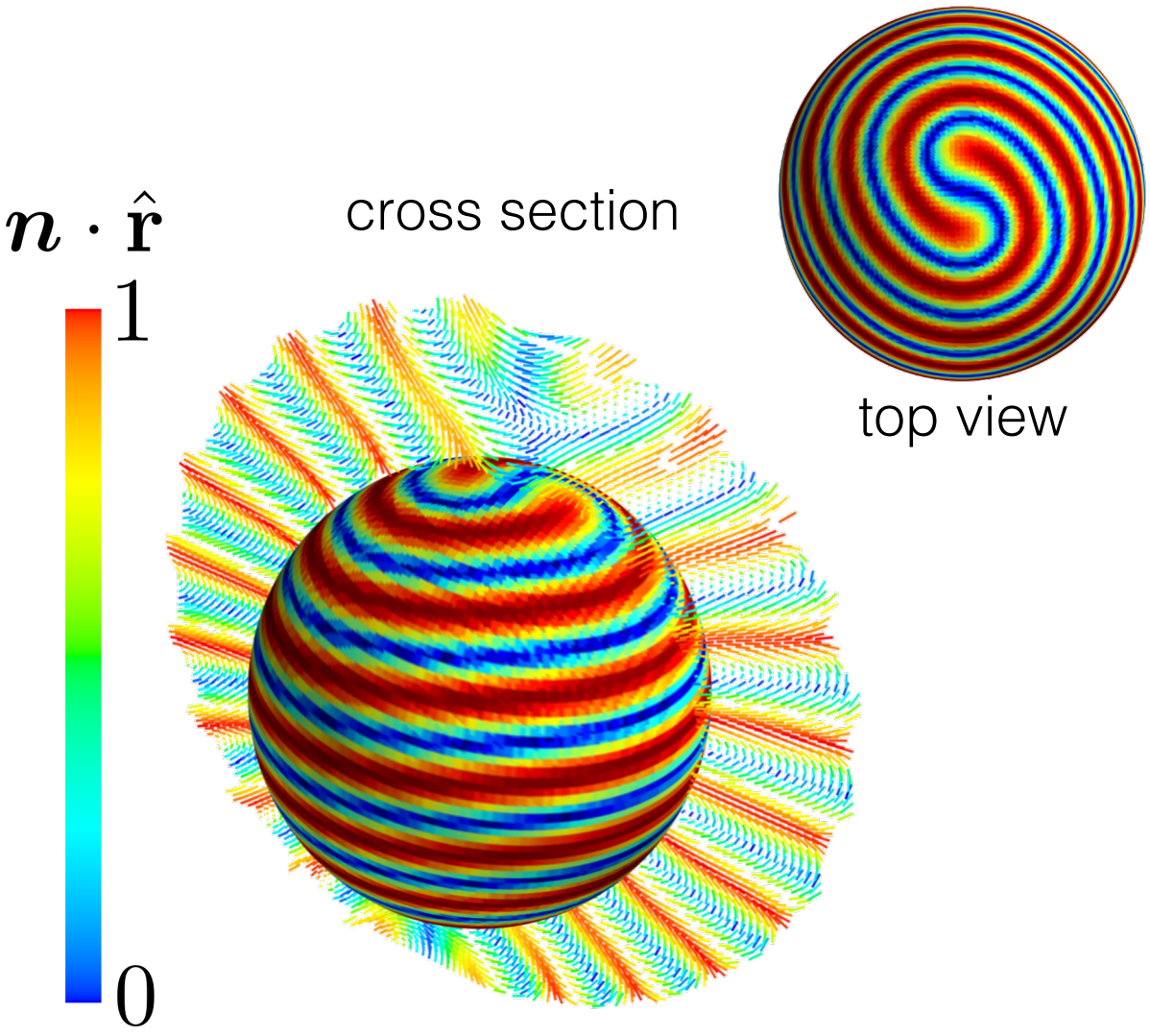


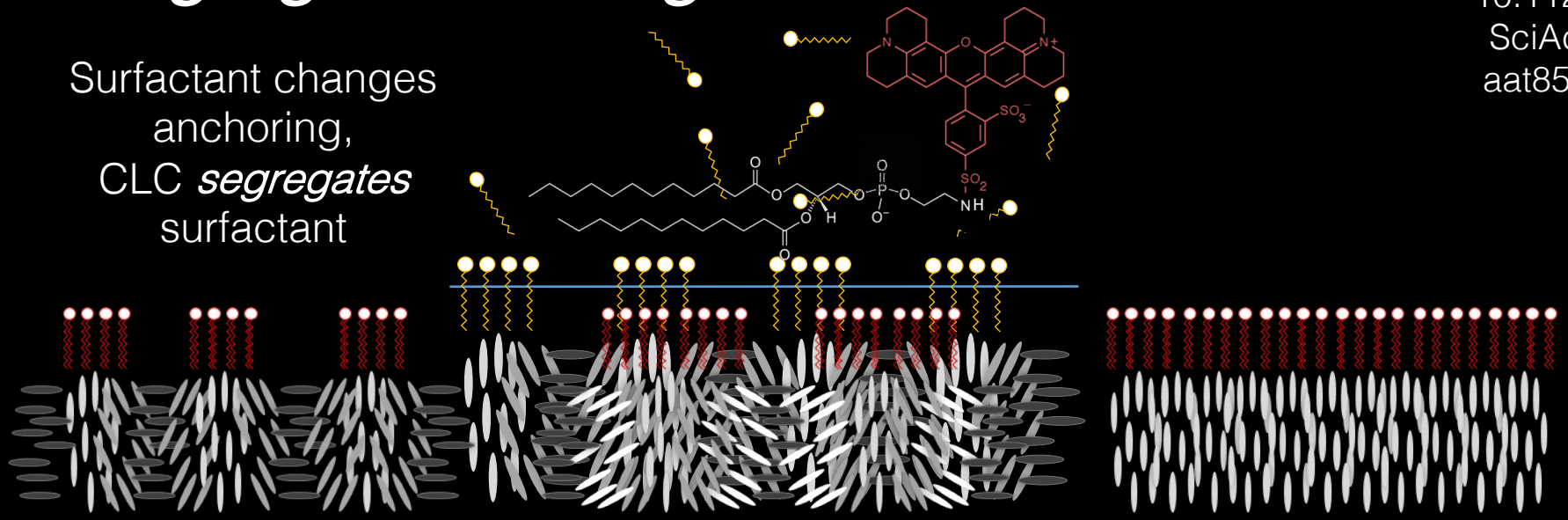
published in PRX
DOI:
10.1103/PhysRevX.
7.041029

Changing anchoring with surfactant

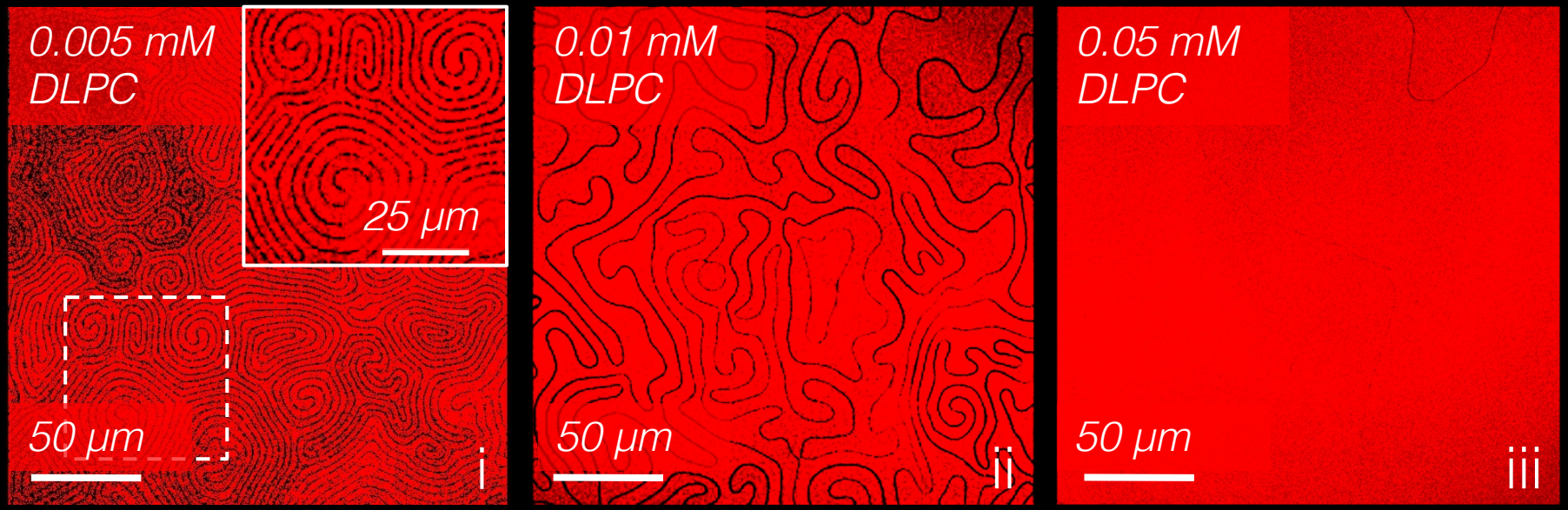
L. Tran

DOI: 10.1126/SciAdv.aat8597

Surfactant changes anchoring, CLC *segregates* surfactant

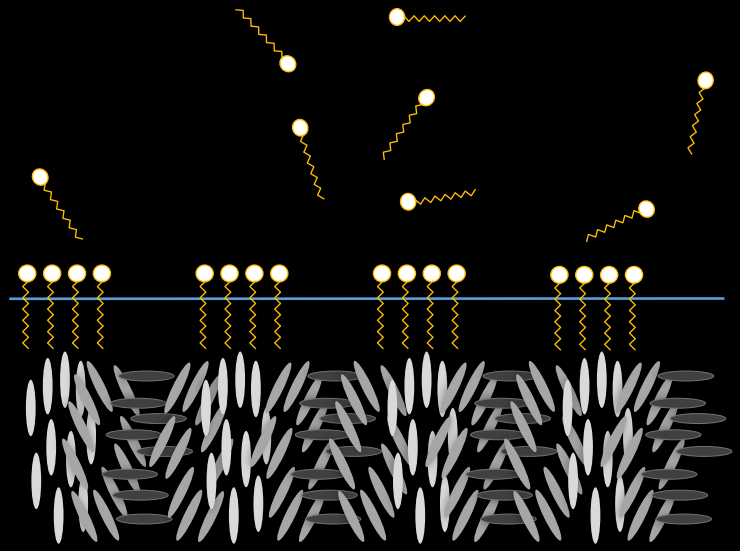


Flat cholesteric film: Fluorescently labeled lipid



Changing anchoring with surfactant

L. Tran DOI: 10.1103/PhysRevX.7.041029



Shell in 10 mM SDS, 0.1M NaCl

SDS is washed away

Planar to perpendicular

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M. Lavrentovich & L. Tran *Phys. Rev. Research* (2020) 2:023128

Changing anchoring…

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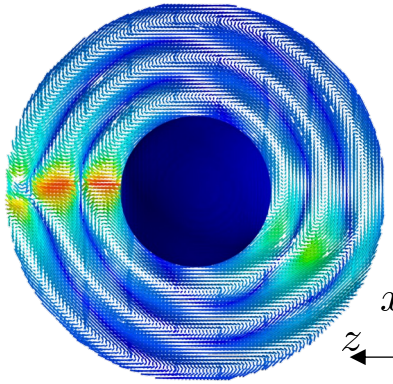
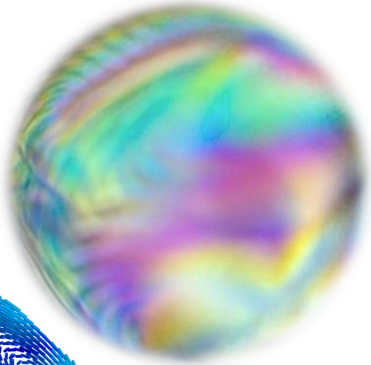
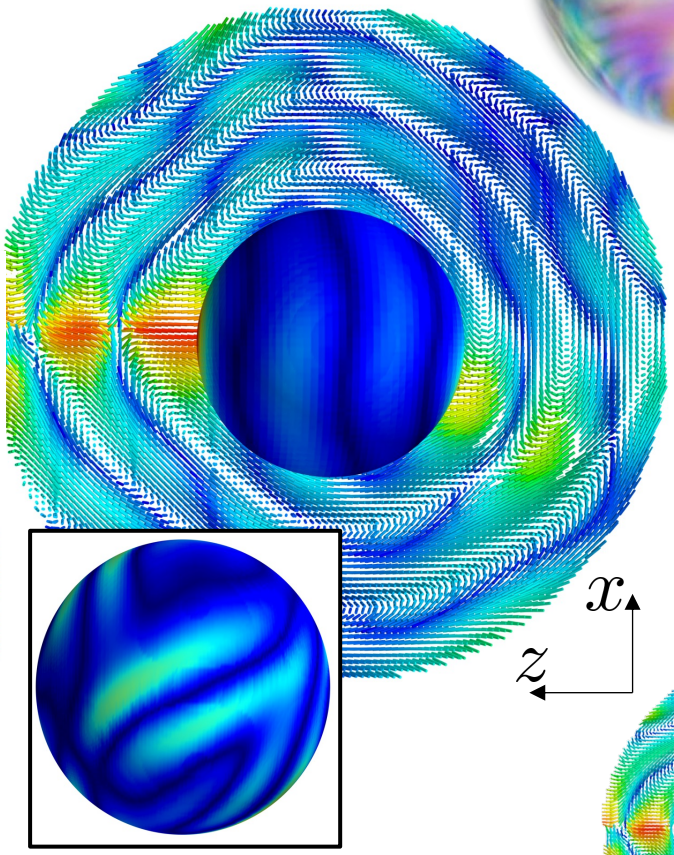
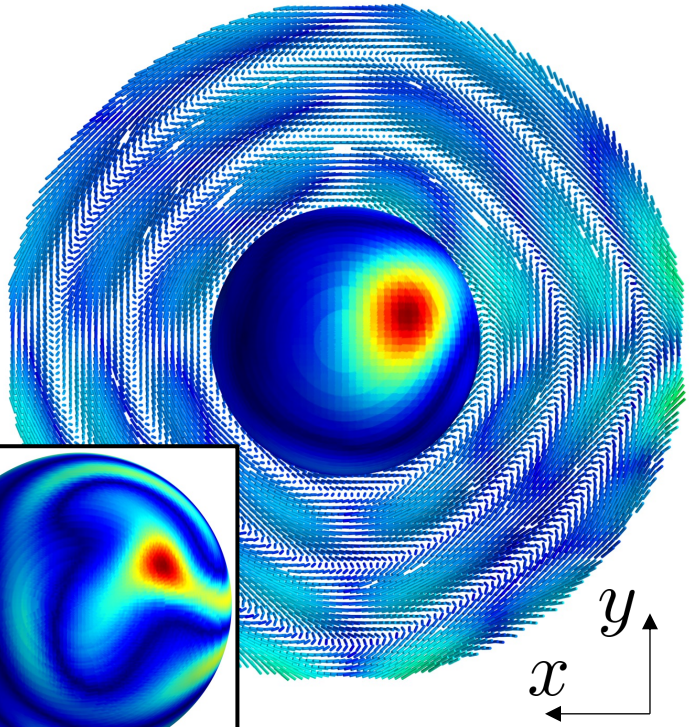


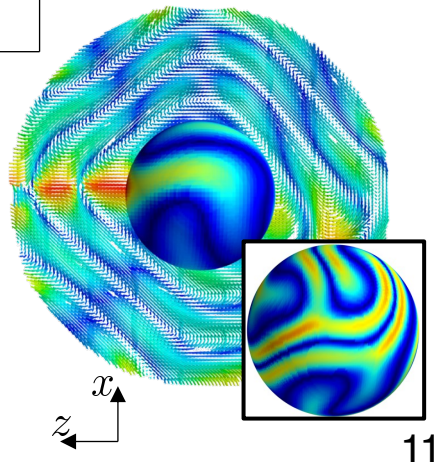
2.1 μm thick
1.2 μm pitch

2×10^{-4} J/m^2
perpendicular
anchoring









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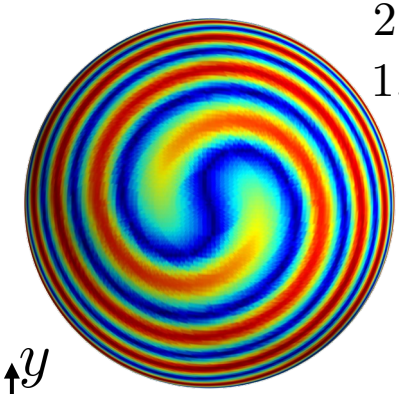
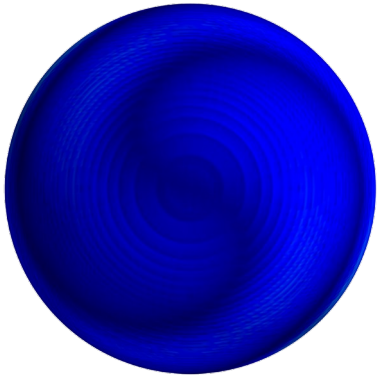
M. Lavrentovich & L. Tran *Phys. Rev. Research* (2020) **2**:023128

Changing anchoring…

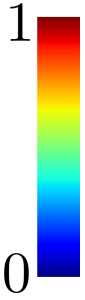
L. Tran DOI: 10.1103/PhysRevResearch.2.023128

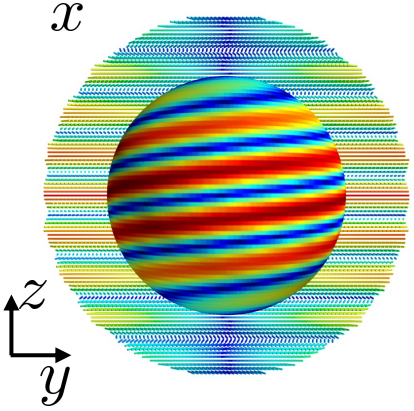


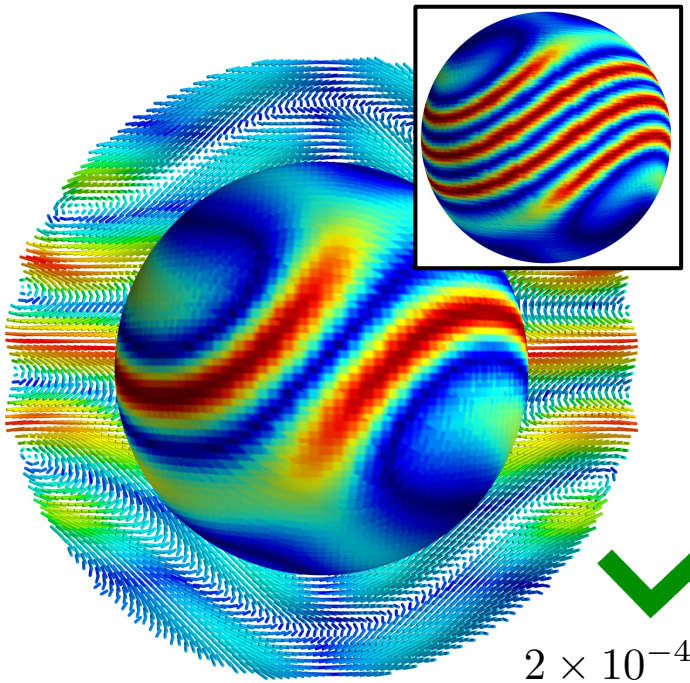
2.1 μm thick
1.2 μm pitch

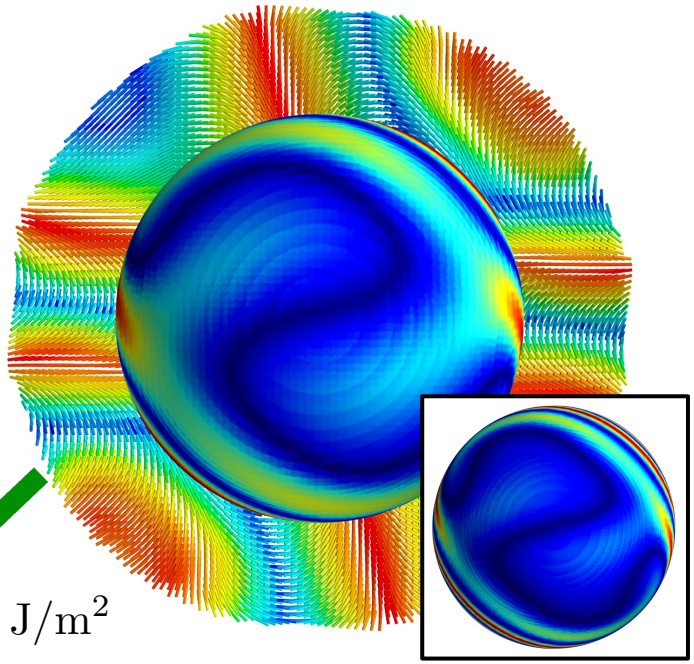


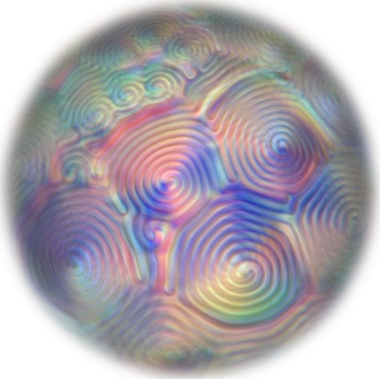
2×10^{-5} J/m^2
planar
anchoring



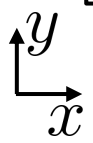








2×10^{-4} J/m^2
planar
anchoring



Undulations? Some history…

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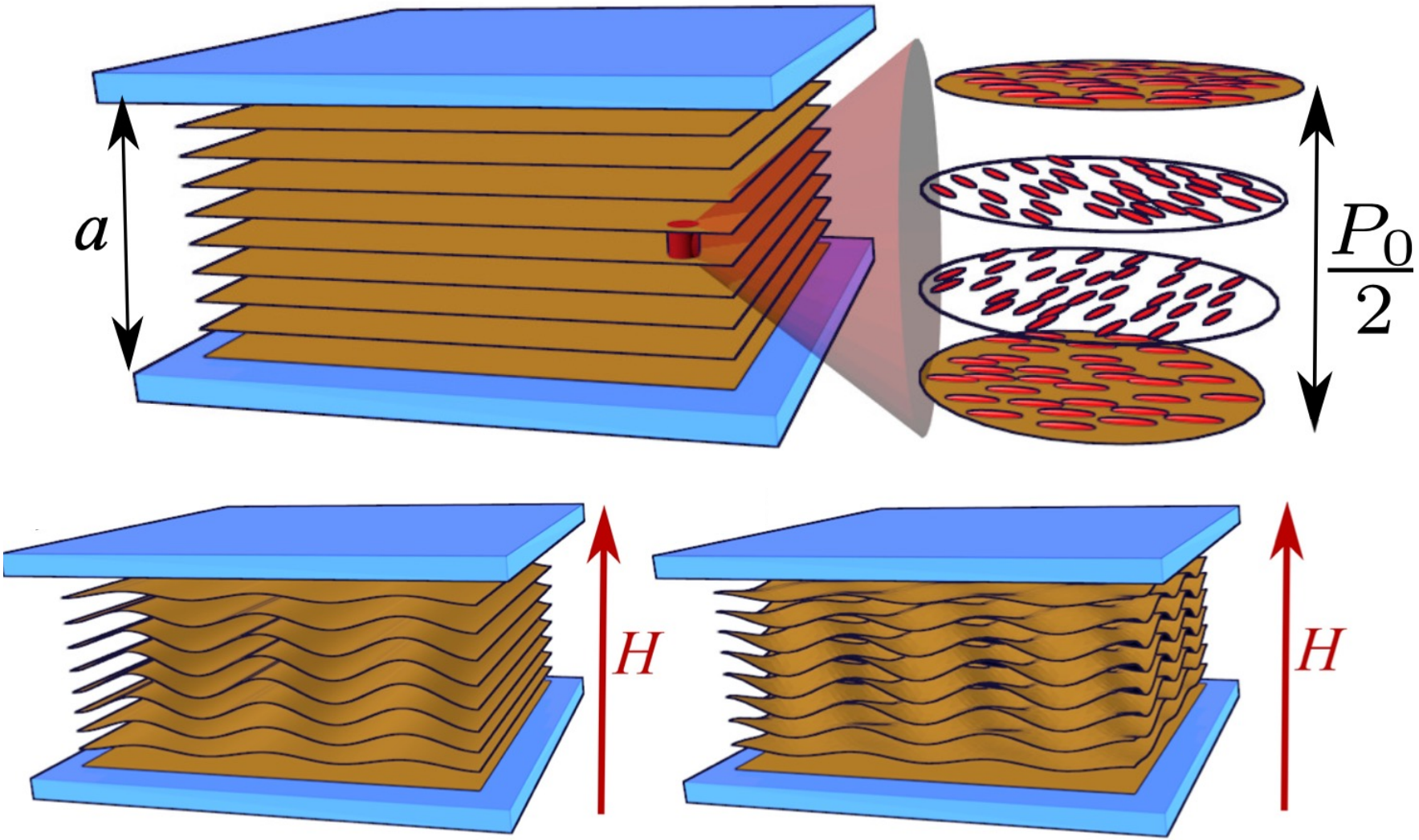
Cholesterics strained by external fields



Initial studies by W. Helfrich (1970) and J. P. Hurault (1973)

Helfrich-Hurault Instability

Helfrich-Hurault in experiments

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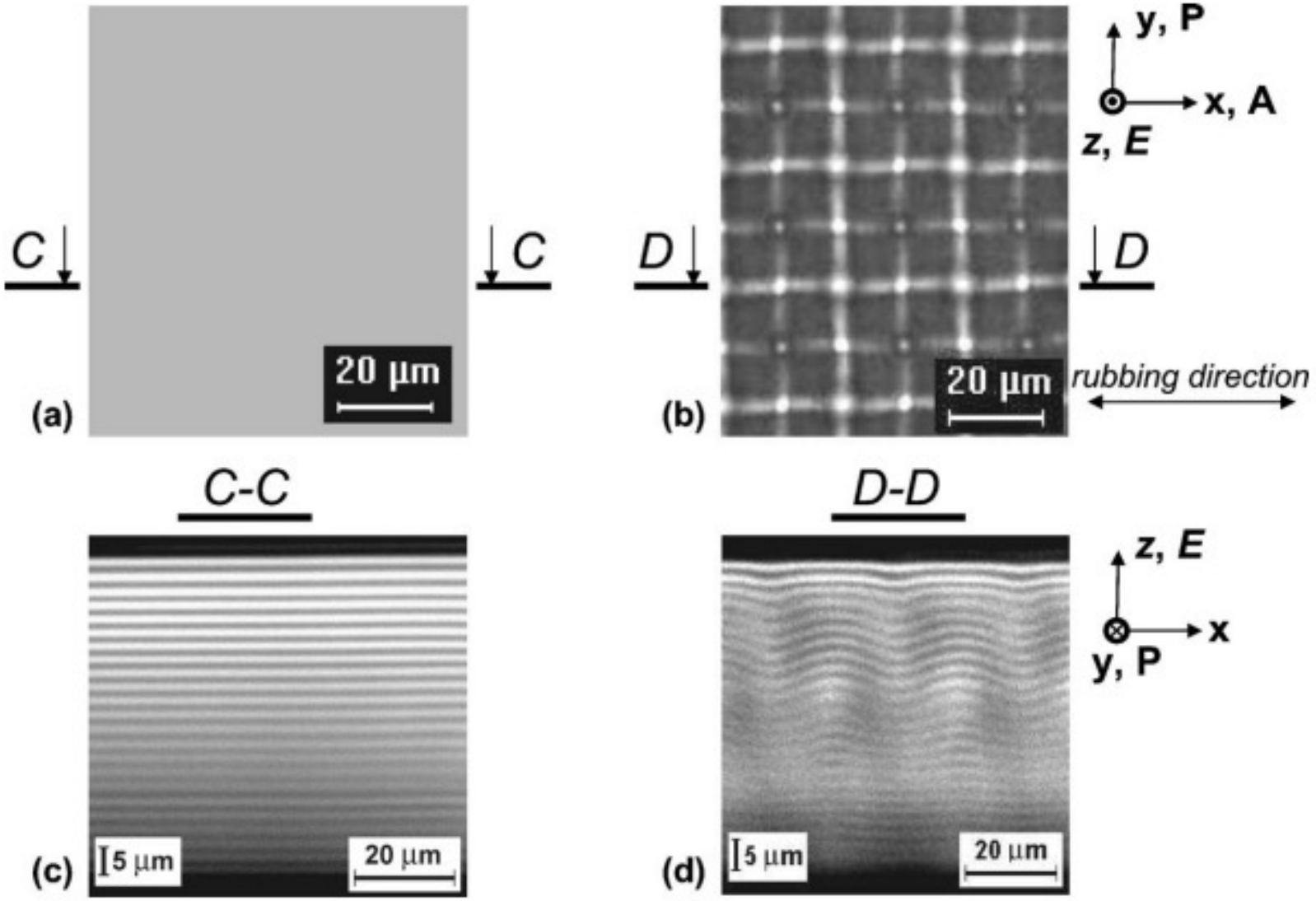

B. Senyuk, *et. al. Phys. Rev. E* (2006) **74**:011712

Helfrich-Hurault also for smectics

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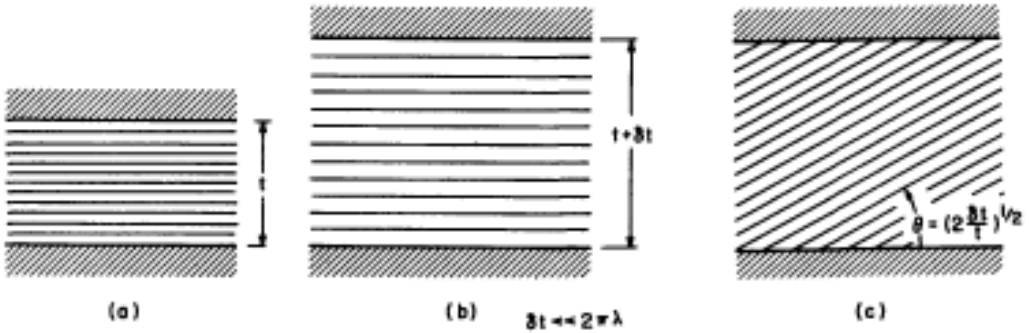
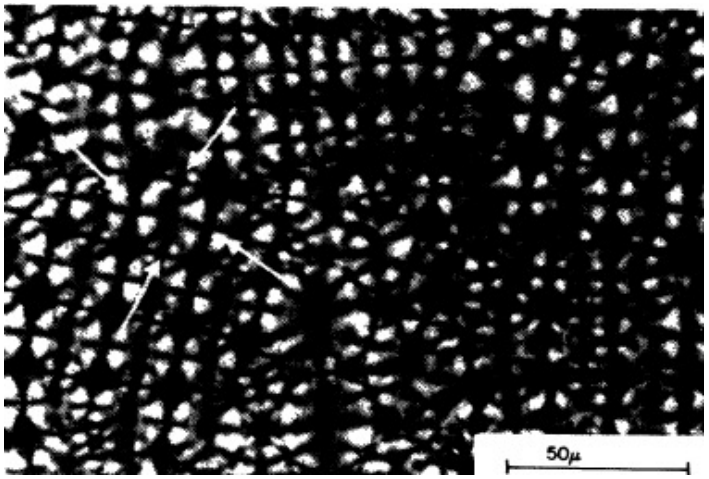
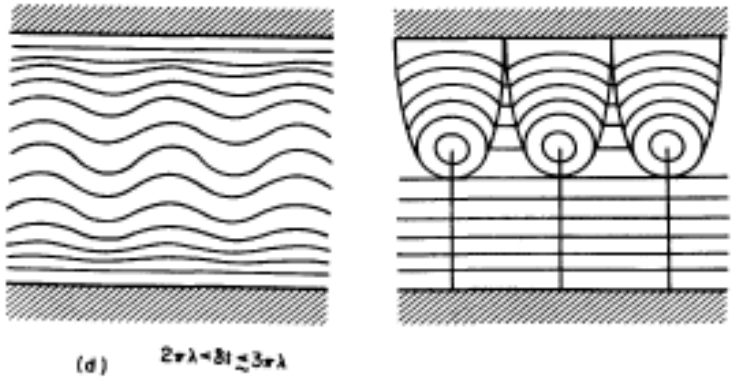
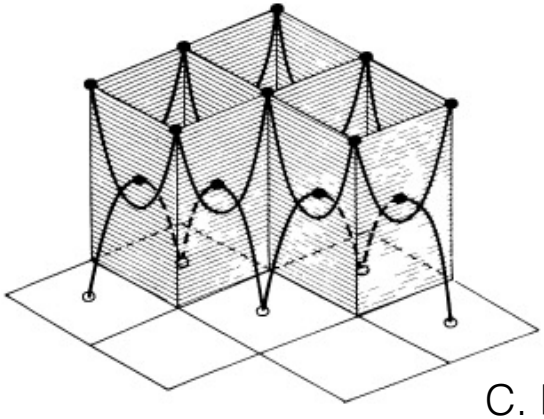
Under mechanical strain





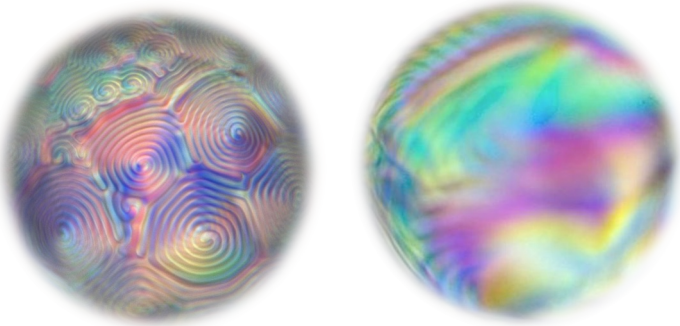
N. Clark & R.B. Meyer,
Appl. Phys. Lett.
(1973) **22**:493

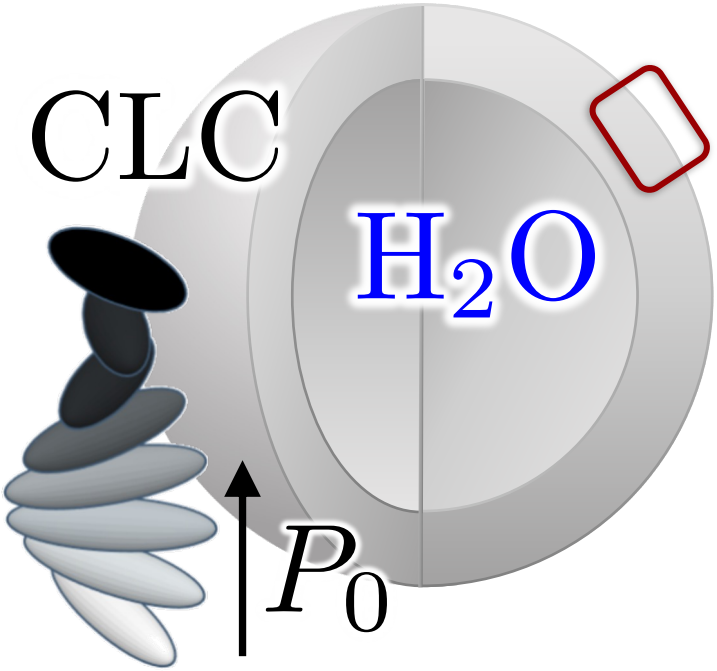


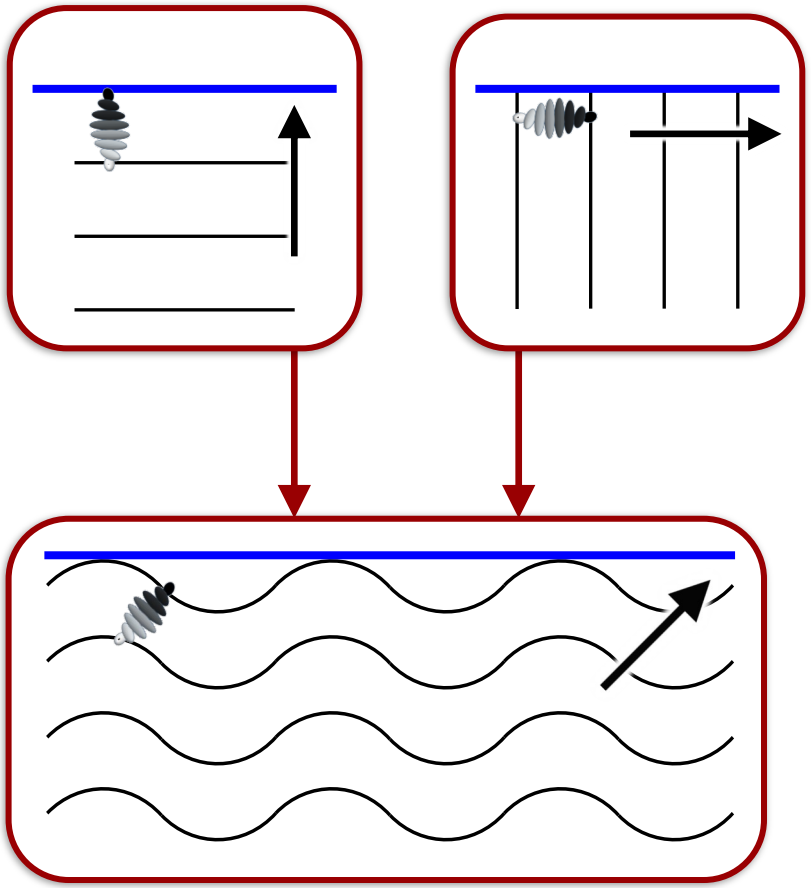


C. Rosenblatt, *et al.*
Journal de Physique
(1977) **38.9**:1105-1115

Proposed mechanism: surface "field" *L. Tran*







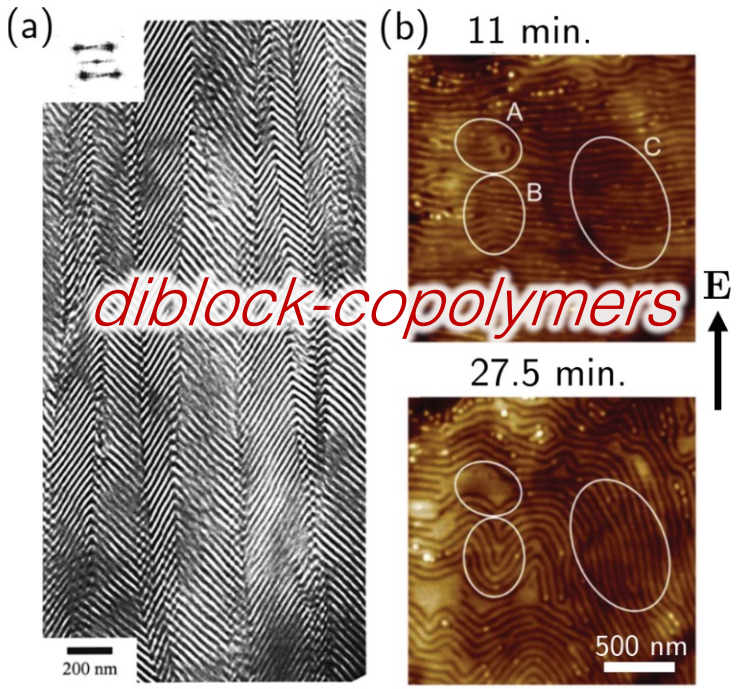
$$W_c \approx 10^{-5}\ \mathrm{J/m^2} \qquad \lambda_x^* \equiv 2\pi/q_x^* \approx 2P_0$$

M. Lavrentovich & L. Tran *Phys. Rev. Research* (2020) **2**:023128

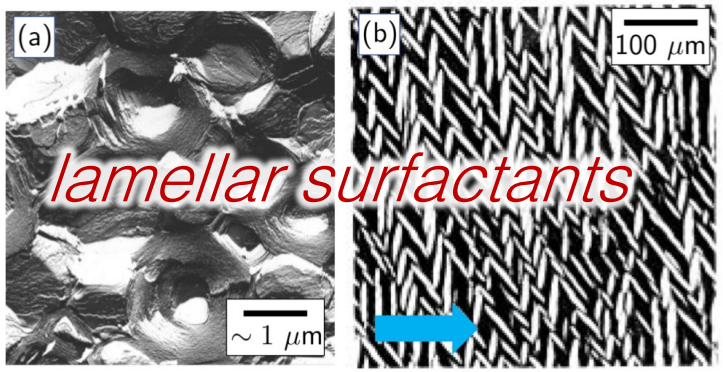
Helfrich-Hurault in other materials

L. Tran

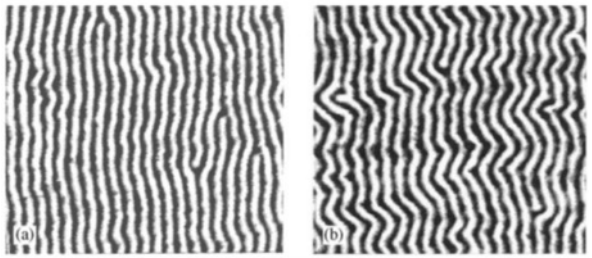
DOI: 10.48550/arXiv.2109.14668
Accepted in Rev. Mod. Phys.

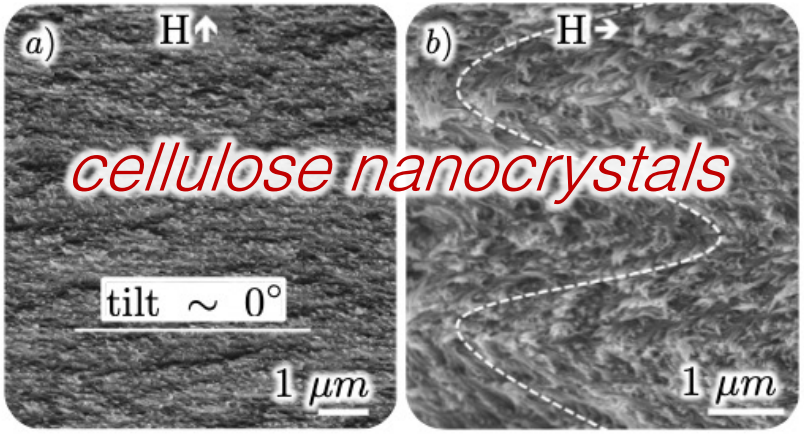


diblock-copolymers



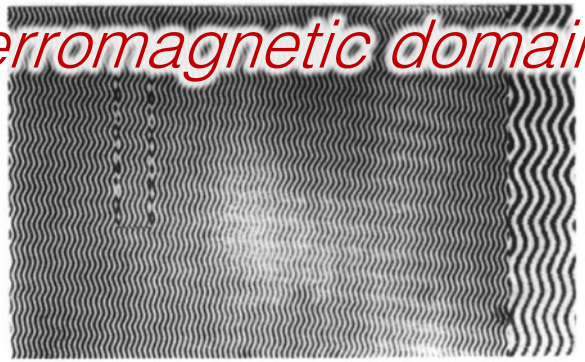
lamellar surfactants





cellulose nanocrystals

ferromagnetic domains



Y. Cohen *et al. Macromolecules* (2002) **33**(17):6502-6516; Liedel *et al. Small* (2015) **11**:6058-6064.
T. Gulik-Krzywicky, *et al. Langmuir* (1996) **12**:4668-4671; L. Ramos, *et al. Eur. Phys. J. B* (1999) **8**:67-72.
B. Frka-Petesic *et al. Adv. Mater.* (2017) **29**(32):1-7; M. Demand *et al. J. Magn. Magn. Mater.* (2002) **247**:147-152

Future directions

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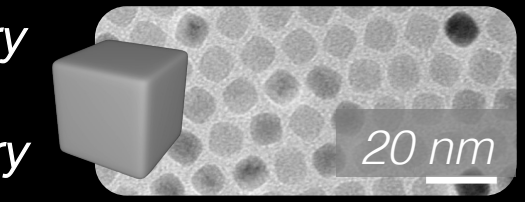
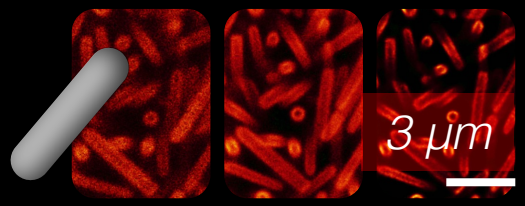
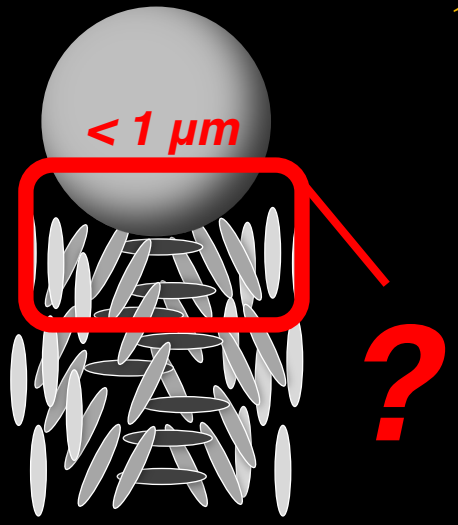
1

particle assembly → geometry & chemistry

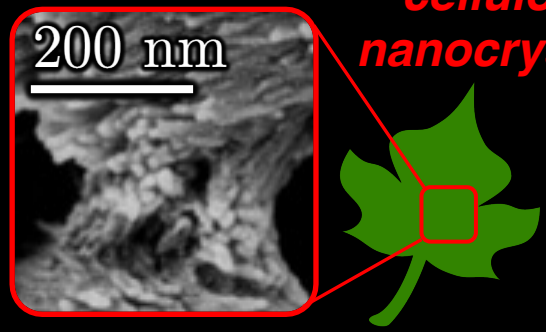
liquid crystal







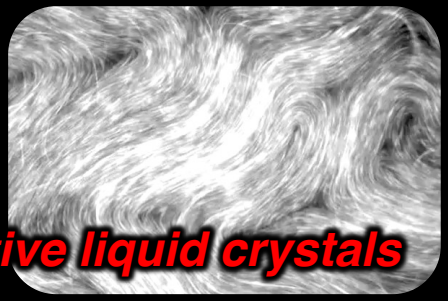
2



cellulose nanocrystals

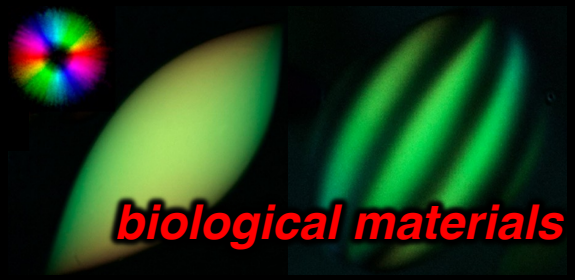
bio-inspired materials

3



active liquid crystals

LC ordering and confinement in biomimetic systems

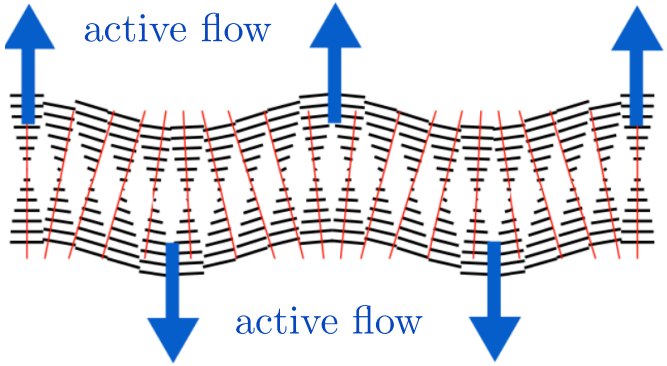


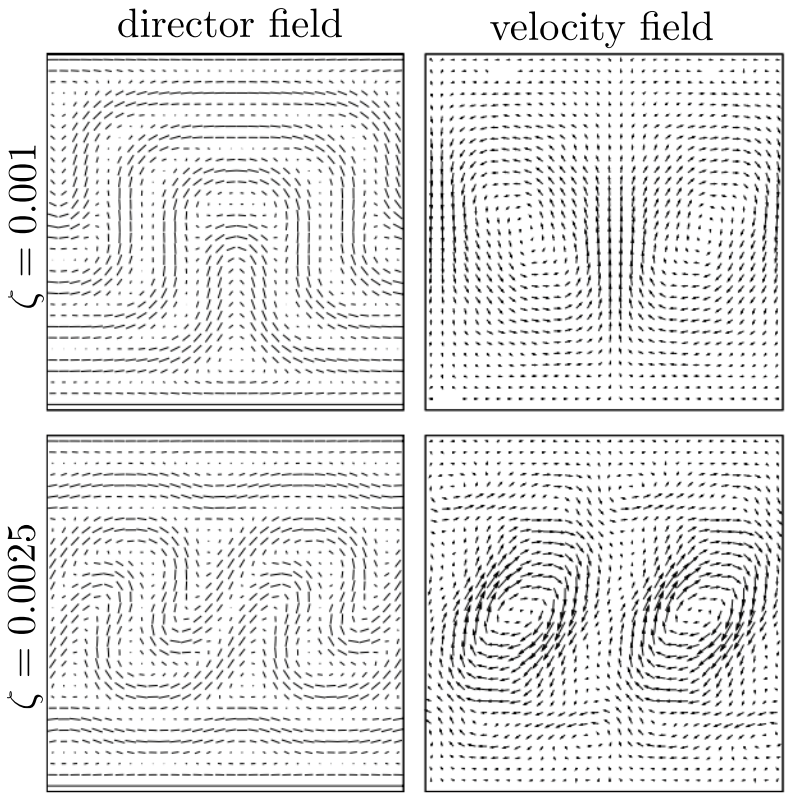
biological materials

Wang, D., et al. *Nat. commun.* (2018), 9:1-10.; Ye, C. et al. *ACS Nano* (2015), 9:10887-10895.; Majoinen, J., et al. *Cellulose* (2012) 19:1599-1605. ; G. Agez, et al. *Acta Biomaterialia* (2017), 48:357-367.; Kuijk, A., et al. *Particle & Particle Systems Characterization* (2014), 31:706-713. & *JACS* (2011), 133:2346-2349.; Youtube, Dogic Lab; Bagnani, M., et al. *ACS Nano* (2019), 13:591-600.

Helfrich-Hurault in bio/active matter

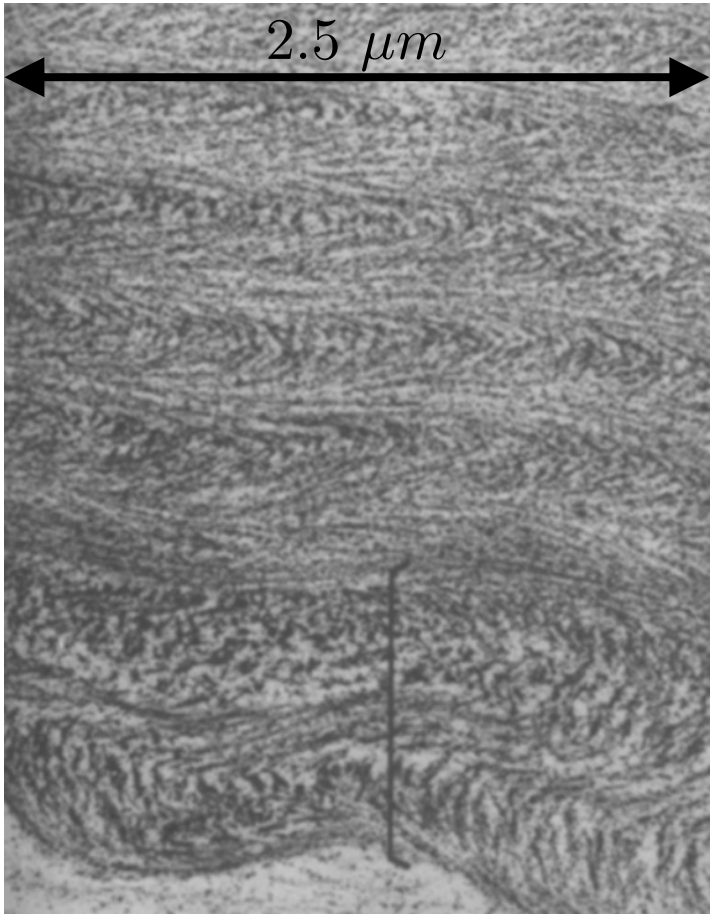
L. Tran DOI: 10.48550/arXiv.2109.14668
Accepted in Rev. Mod. Phys.





C.A. Whitfield, *et al. Eur. Phys. J. E* (2017) **40**:50

Elongation zone of mung bean seedling



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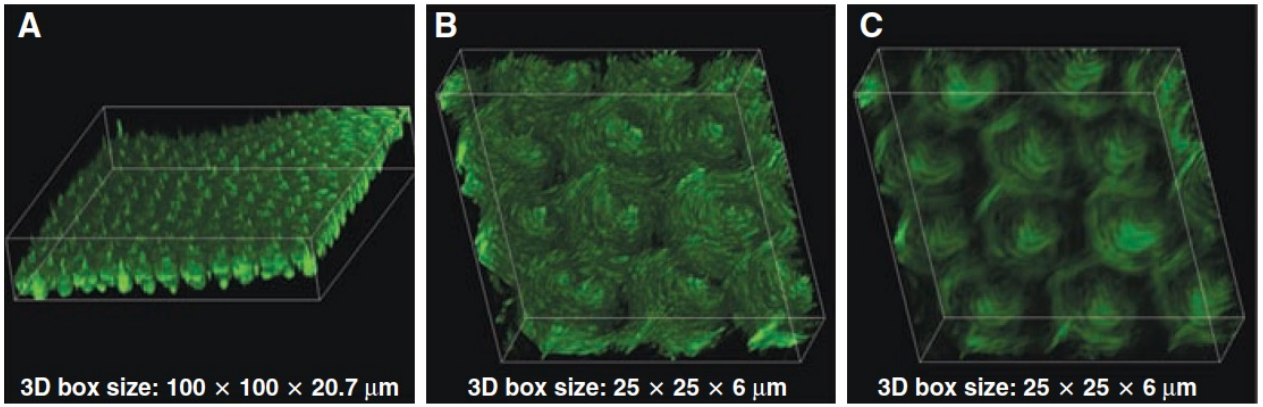
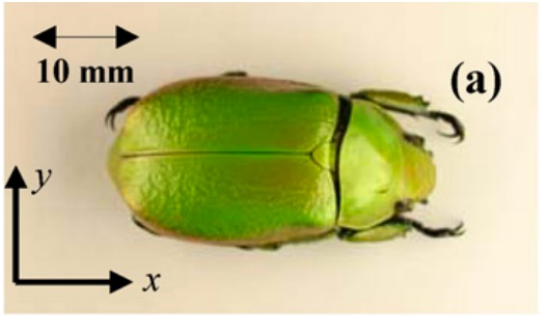
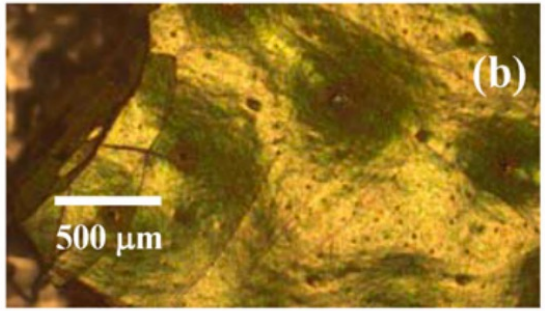
Cholesterics in the natural world

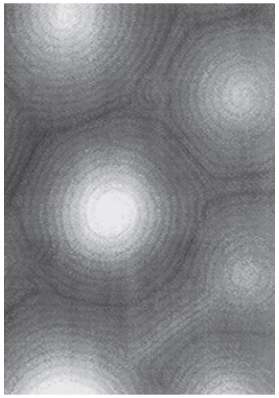
L. Tran

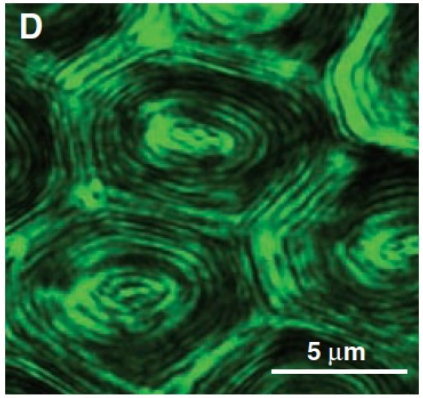
Structural color

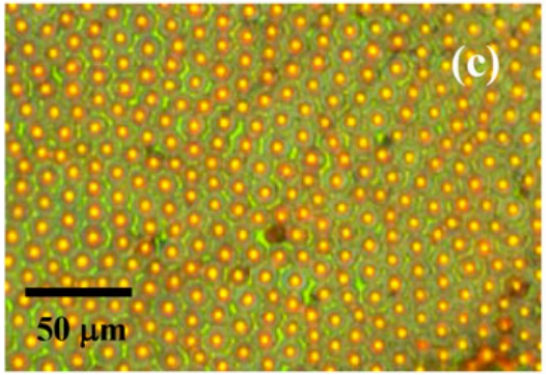


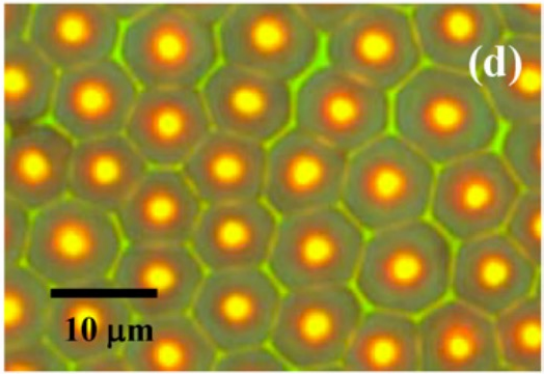












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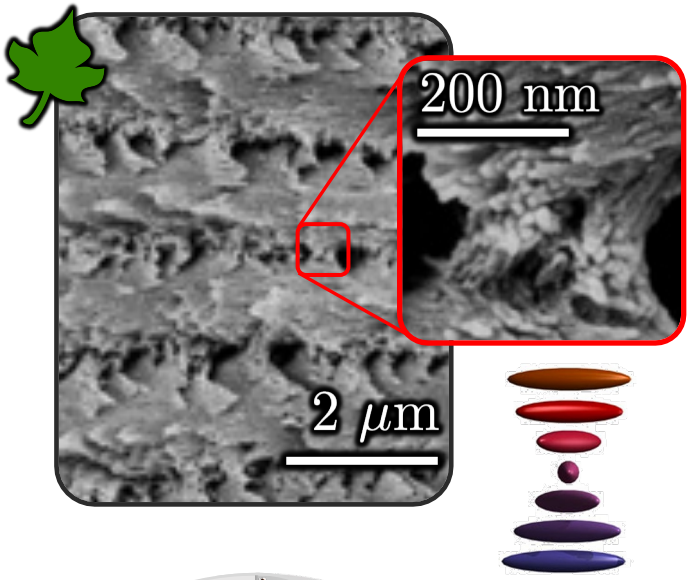
Cellulose nanocrystals

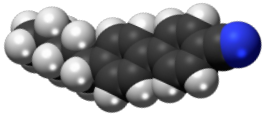
L. Tran

From molecular to colloidal LCs

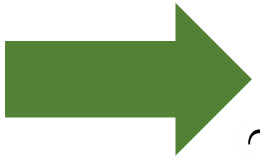
Diogo Saraiva

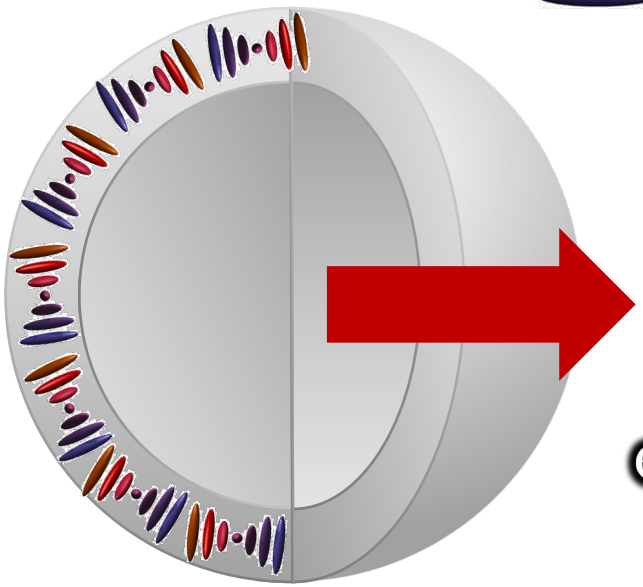


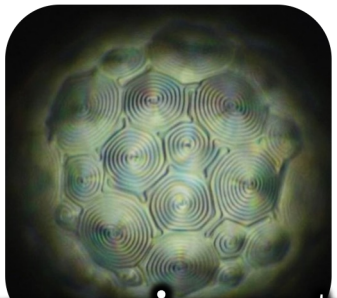
2 nm



small molecule







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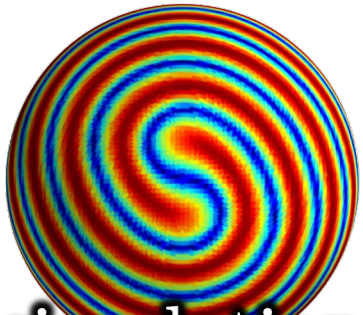
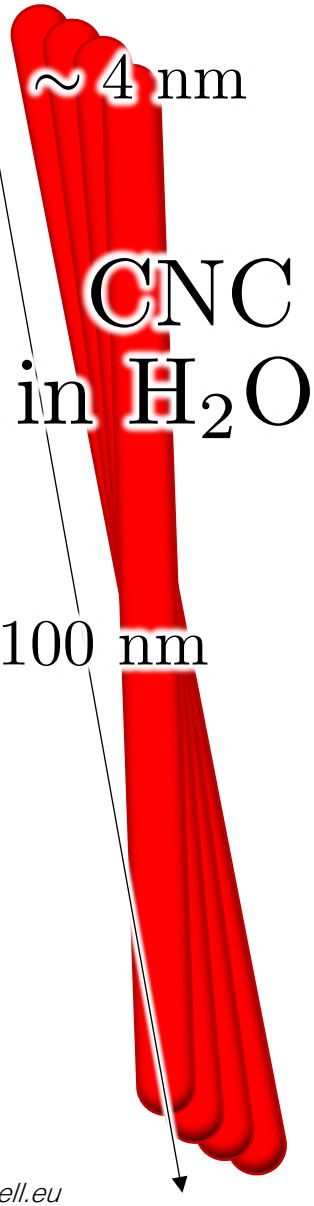


experiments simulations



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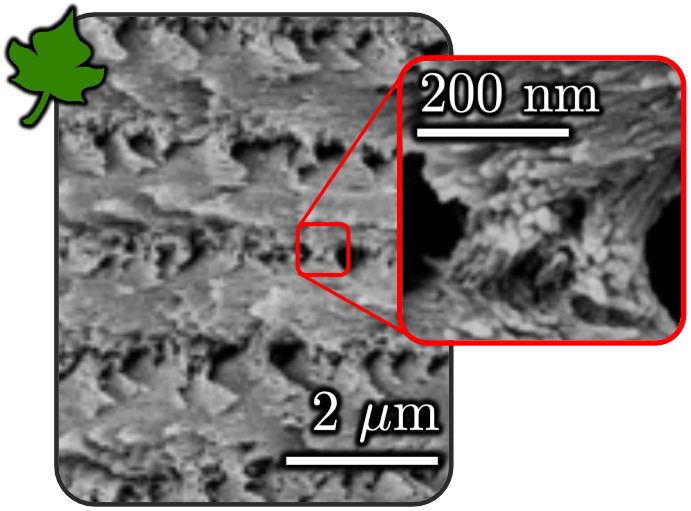
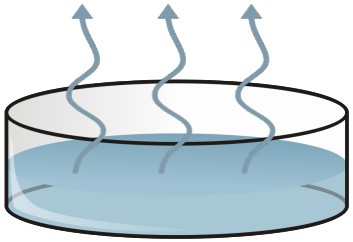
J. Majoinen, ... D.G. Gray, *Cellulose* (2012) 19:1599-1605.

Photonic CNC assembly

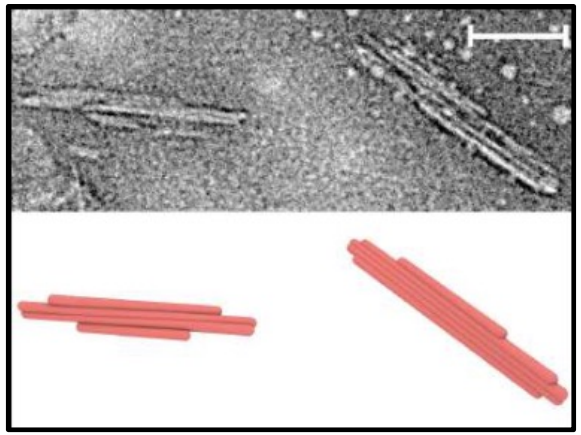
L. Tran

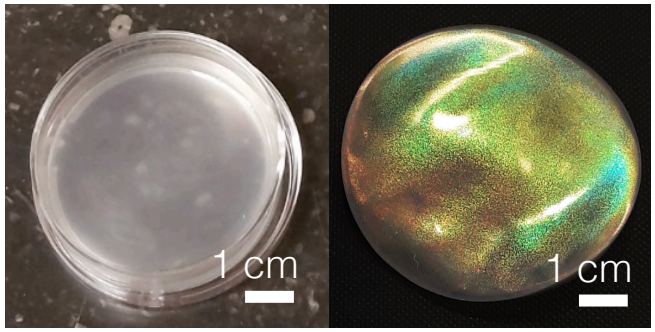
Diogo Saraiva



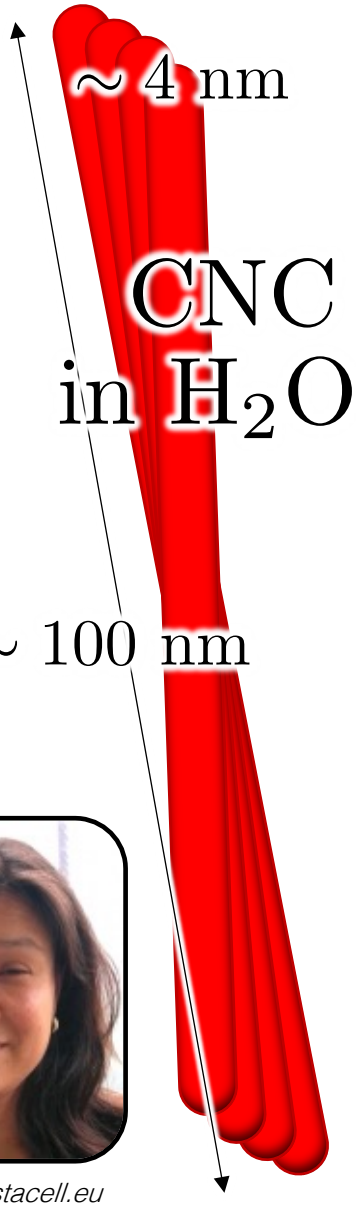


CNC bundles





Marjolein Dijkstra



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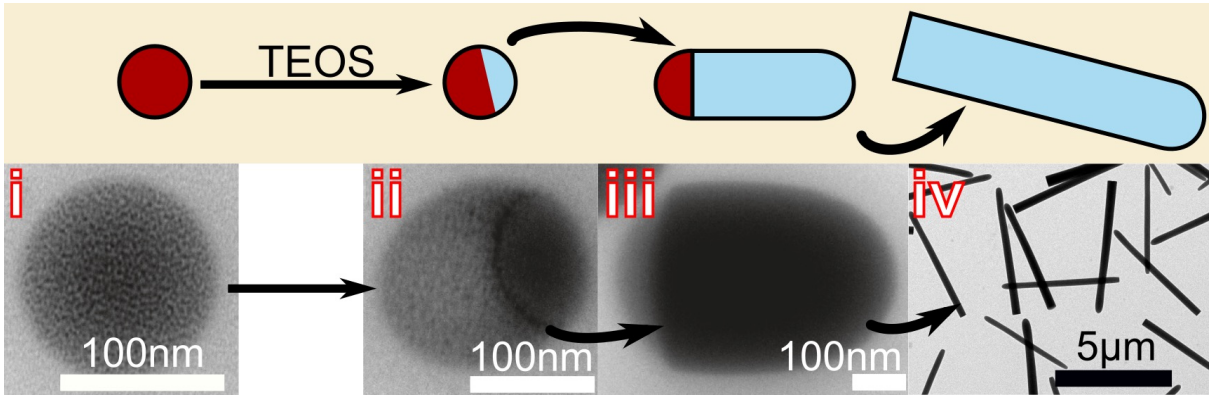
J. Majoinen, ... D.G. Gray, *Cellulose* (2012) 19:1599-1605.

Confinement of colloidal nematics

Ethan Jull



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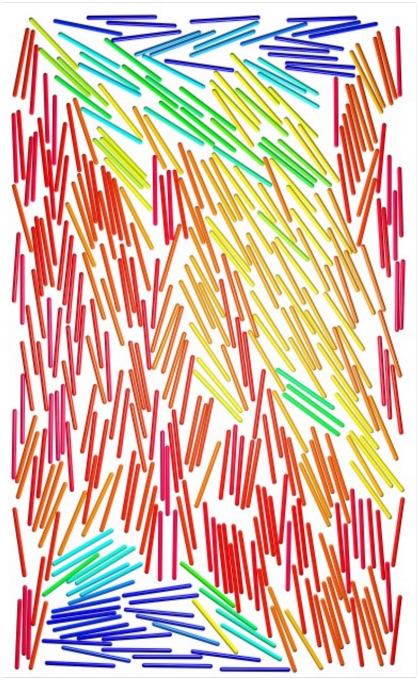
Gerardo C. Villalobos



Rama Kotni

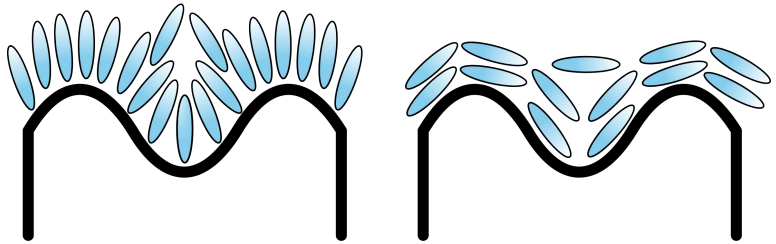
Marjolein Dijkstra

Alfons van Blaaderen

Anchoring of colloidal nematics

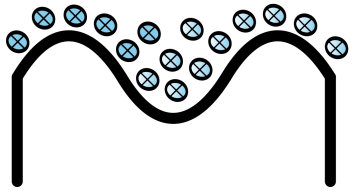
L. Tran

Ethan Jull



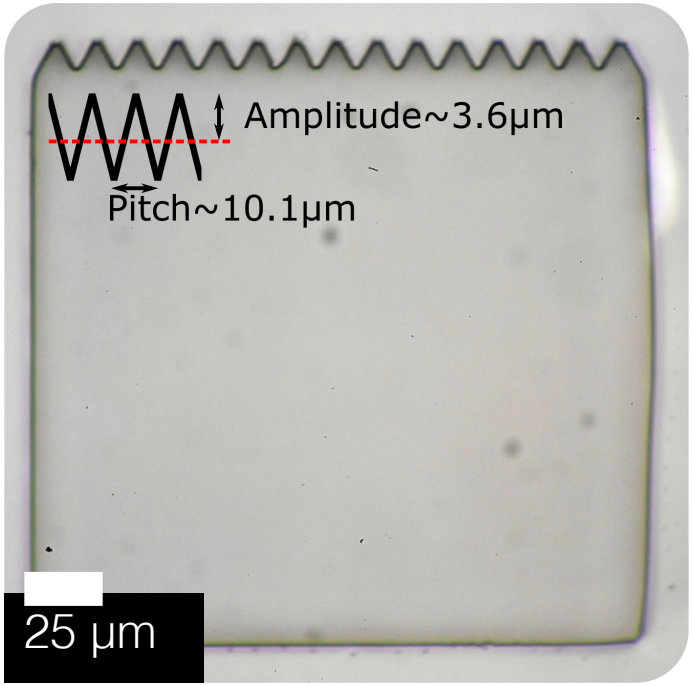
High elastic distortion

Berreman Model



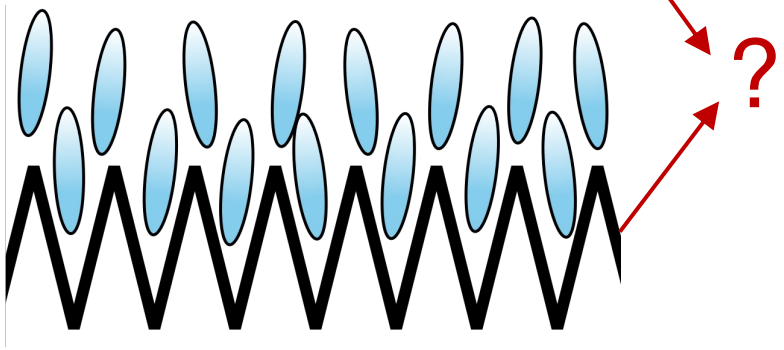
Low elastic distortion

D. W. Berreman, *Phys. Rev. Lett.* 28 (1972)



Features approach size of the mesogen

$$f_s = -\frac{1}{2}W(\boldsymbol{n}\cdot\boldsymbol{e})^2$$

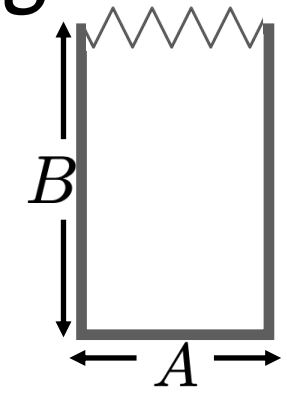


Anchoring of colloidal nematics

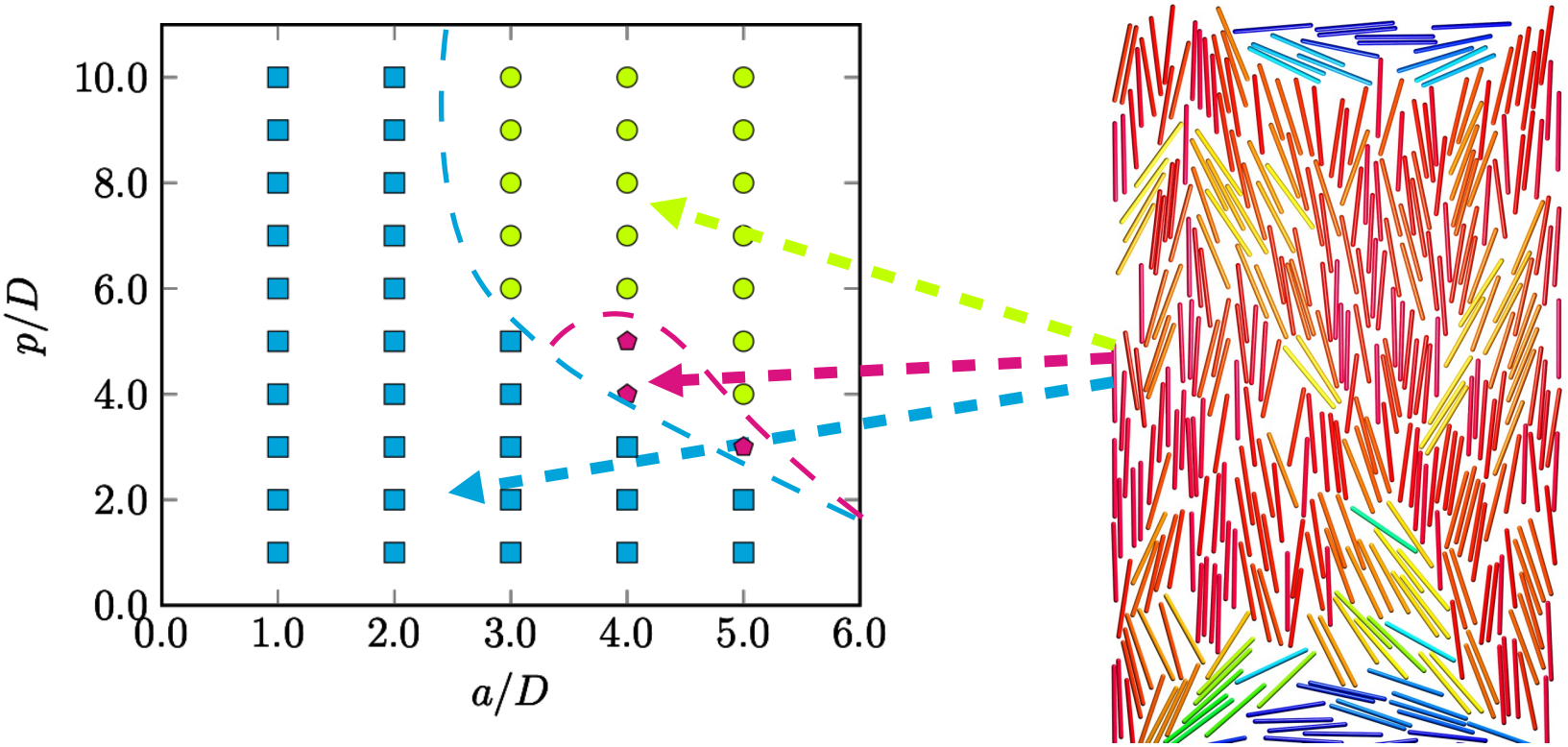
L. Tran

Ethan Jull

Confined Colloidal System – Anchoring



$$A/L = 6$$
$$A/B = 0.6$$



Gerardo C. Villalobos & Marjolein Dijkstra

Conclusions

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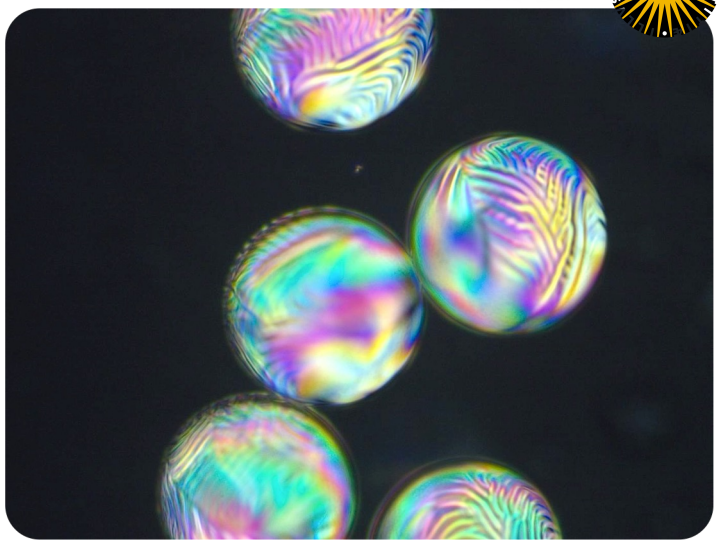
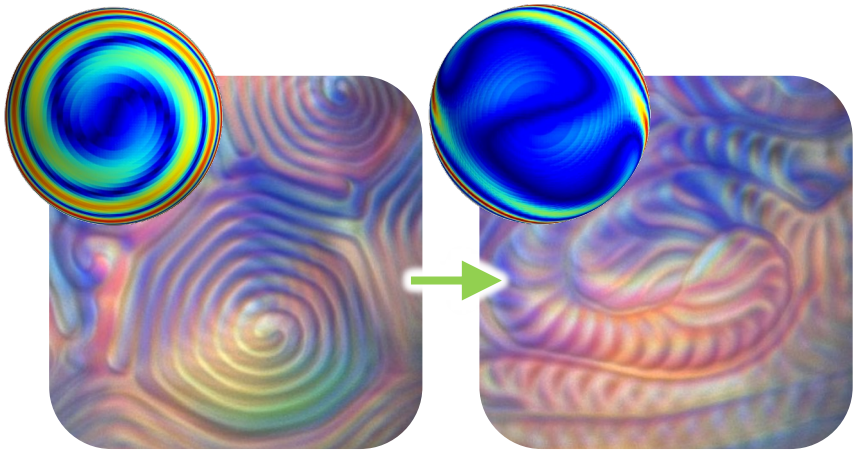
L. Tran



- *Helfrich-Hurault Instability:*
  Strain in periodic systems generates undulations
  - can be induced from surfaces
  - is widely applicable to lamellar systems
  - DOI:10.48550/arXiv.2109.14668



- *My collaborators in this work:*
  - Max Lavrentovich (UT Knoxville)
  - Teresa Lopez-Leon (ESPCI)
  - Randy Kamien (UPenn)
  - Christophe Blanc (Montpellier)

Thank you:

SIMONS FOUNDATION

MARIE CURIE ACTIONS

NWO