公開用編集版スライド

Observing dynamics of topological defects in liquid crystal

toward understanding their hierarchical structure

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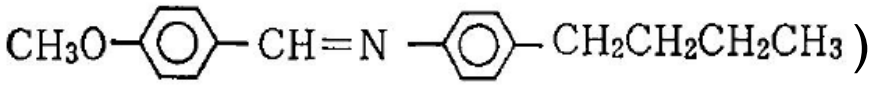
JST PRESTO JST さきがけ「トポロジー」

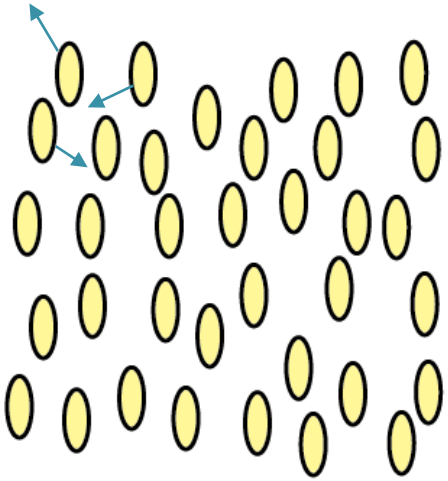
Coworker

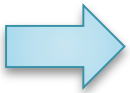
Yohei Zushi 図司陽平 (M1)

What is Liquid Crystal?

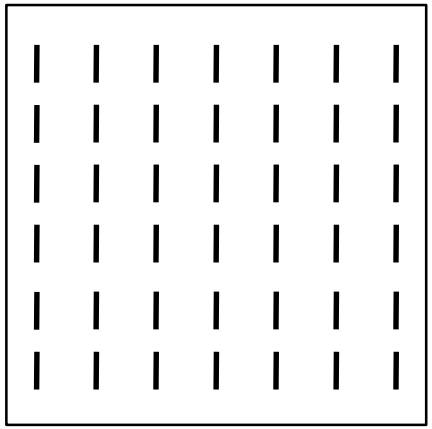
Nematic liquid crystal

- Rod-like molecules (e.g., MBBA )
- nematic phase = liquid-like disordered position, but ordered orientation
- Anisotropic material properties (optic, electric, rheological...)

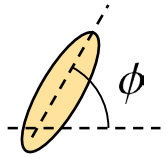




"director field" $\boldsymbol{n}(\boldsymbol{r}, t)$
unit vector indicating
mean orientation



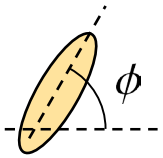
"field of orientation"
(analogous to spin field or phase field)
except $0^\circ = 180^\circ$ (i.e., $\boldsymbol{n}$ is equivalent to $-\boldsymbol{n}$)
Order parameter space $RP^2 = S^2/Z_2$



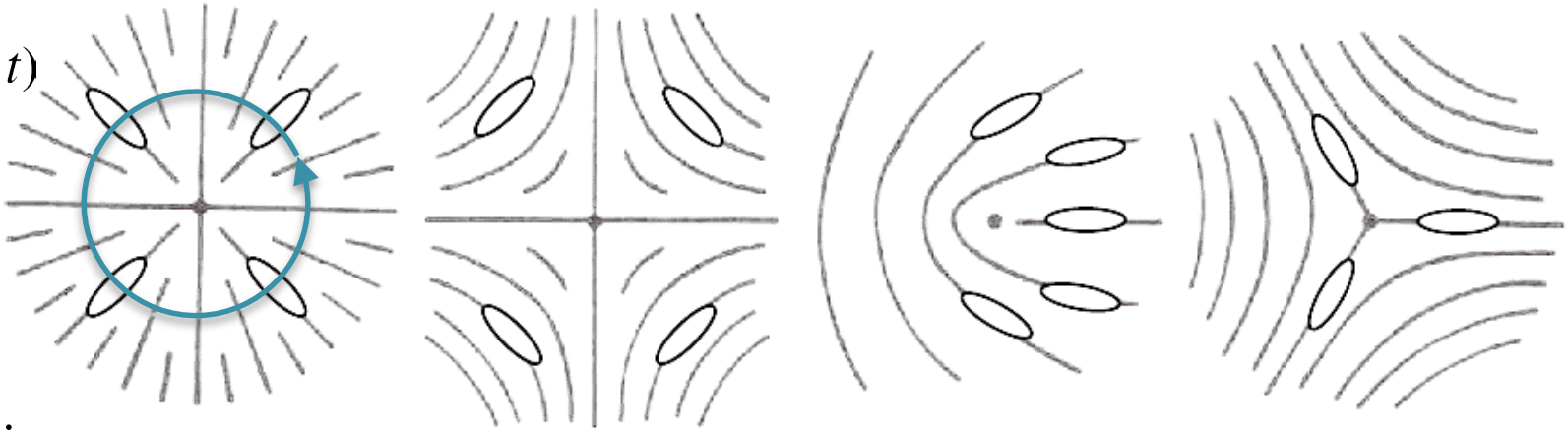
Topological Defects (Disclinations)

for 2D

$$\oint \nabla\phi \cdot \mathrm{d}\boldsymbol{l} = 2\pi k \quad (k : \text{integer or half-integer})$$



$\phi(\boldsymbol{r}, t)$



winding number

$k = +1$ $k = -1$ $k = +1/2$ $k = -1/2$

for 3D...

integer-*k* is *not* truly defects

yet such objects are observable

half-integer-*k* is truly defects

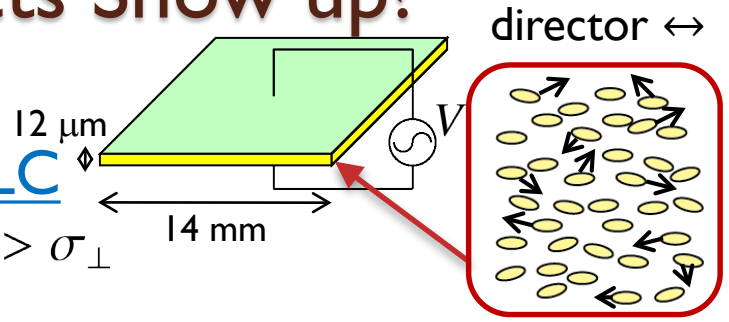
(but $k = \pm 1/2$ are equivalent)

line defects

analogous to quantum vortices in cold atom BEC

[sketch from Chandrasekhar's book]

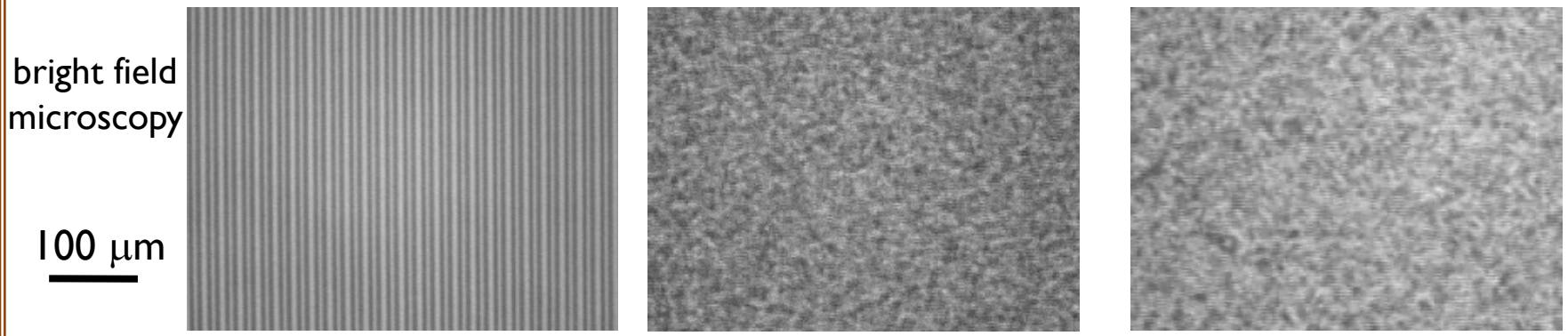
When do Topological Defects Show up?



e.g.) Electro-convection of nematic LC

anisotropic electric properties $\varepsilon_{\parallel} < \varepsilon_{\perp}$, $\sigma_{\parallel} > \sigma_{\perp}$

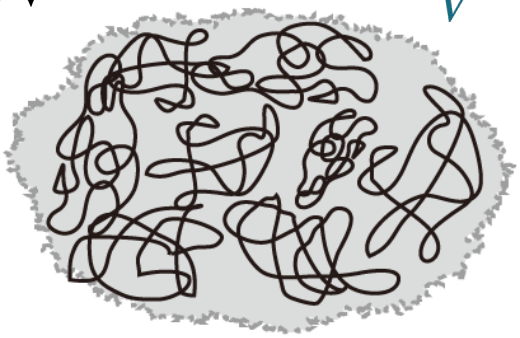
⇨ convection driven by electric field



SKETCH of topological-defect turbulence

※ No one has seen it

⇧ main target of proposal



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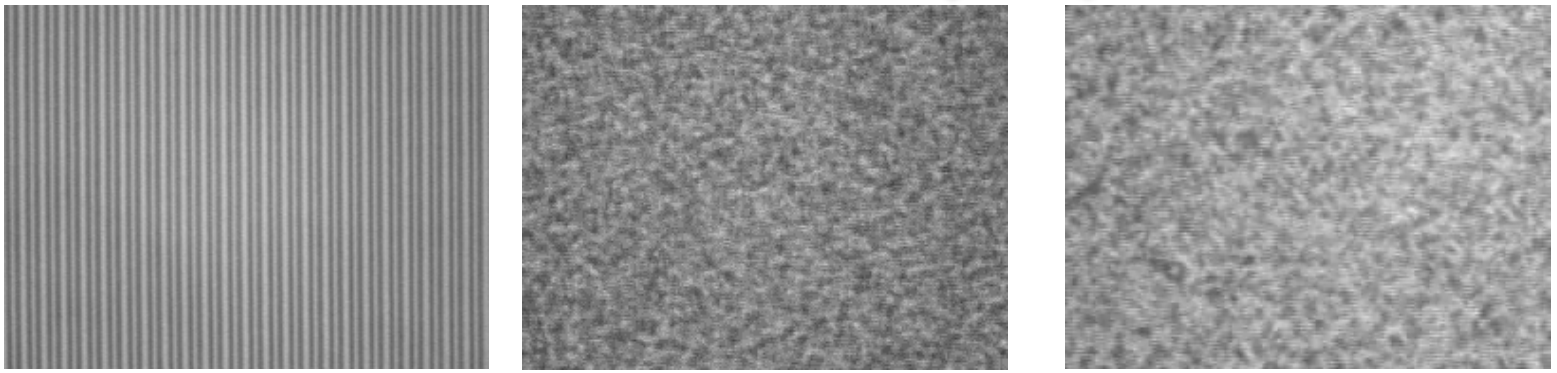
non-eq. phase transition to defect turbulence?



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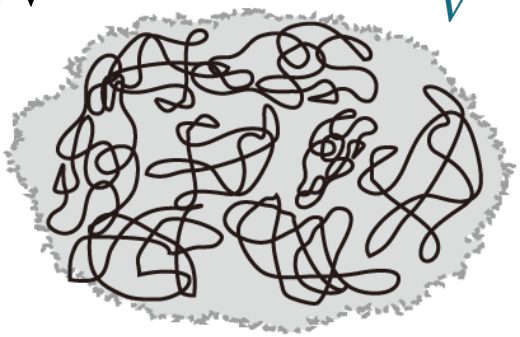
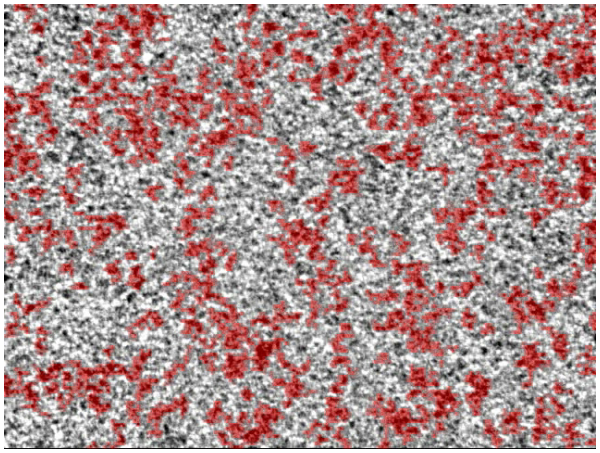


[KaT *et al.* PRL 99, 234503 (2007); 竹内, 物理学会誌 2015年8月号]

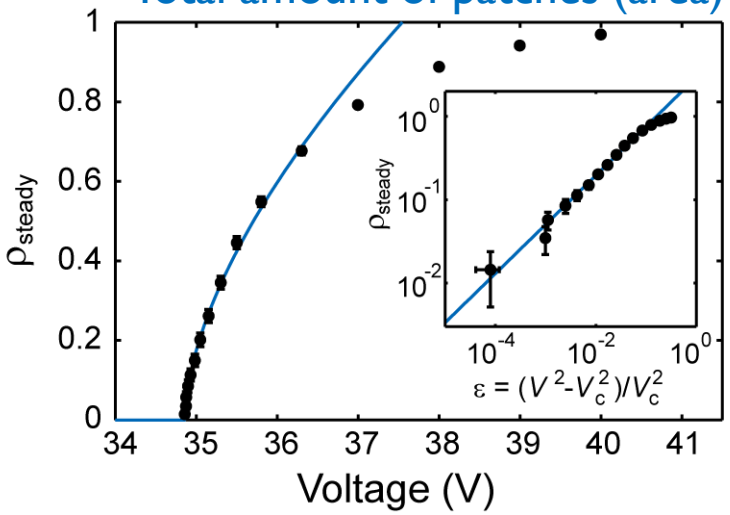
Transition to Defect Turbulence

Localized patches of defect turbulence
near the transition



(red = defect turbulence)

Total amount of patches (area)



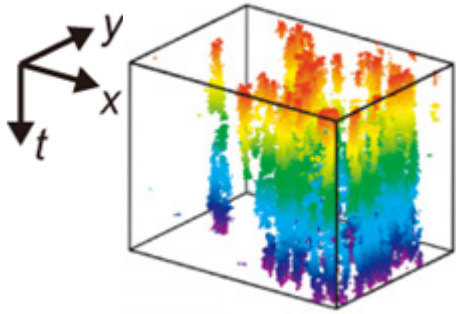
$$\rho_{\text{steady}} \sim (V^2 - V_c^2)^{\beta} \quad \text{with} \quad \beta = 0.59 \pm 0.04$$

agreement with
"directed percolation" class!

$$\beta^{\text{DP}} \approx 0.583$$

Directed percolation (DP)
universality class

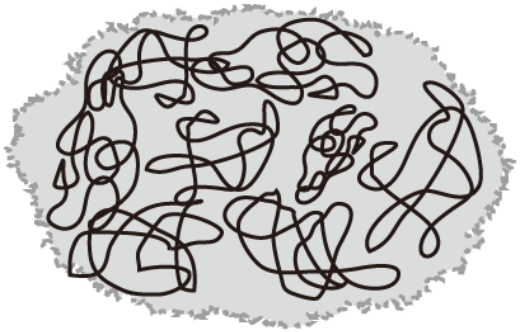
- most fundamental universality class
  for irreversible phase transitions
  "survival or extinction" of active clusters
- recently found in turbulence transition
  in simple fluid (exp't) & cold atom BEC (num)



patches' space-time evolution

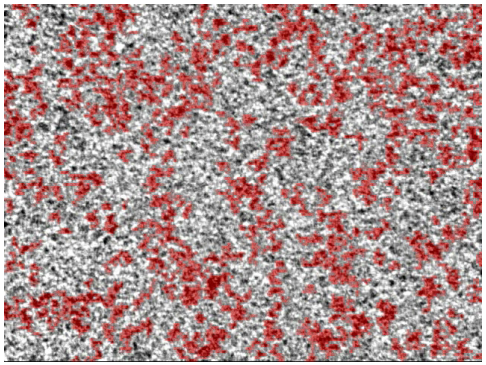
Our Aim

- Direct 3D observation of topological-defect turbulence
  by confocal microscopy techniques



is this sketch true?

- Questions to address:
  - Structure & Dynamics of defects
    How dense & entangled?
    How they move and interact?
  - Why do they form clusters?
  - Why DP class in macro?
    "bridging micro (meso) to macro"
  - Relationship to quantum turbulence?
    Generalities on clustering & hierarchy?



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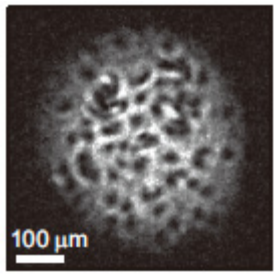

BEC quantum turbulence
[Kwon et al., PRA 2014]