Dynamics of A Growing Nematic Under An External Field

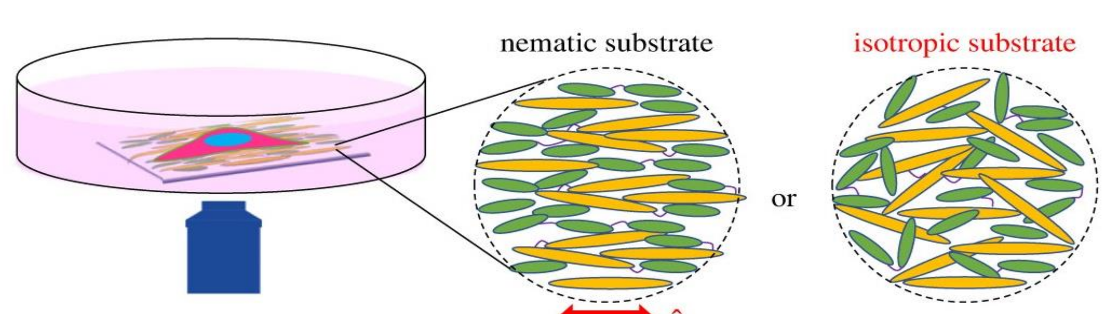
Toshi Parmar[1], Fridtjof Braun[2], Yimin Luo[3], M. Cristina Marchetti[1]

1. Department of Physics, University of California Santa Barbara; 2. Kavli Institute for Theoretical Physics, UCSB;
3. Department of Mechanical Engineering & Materials Science, Yale University

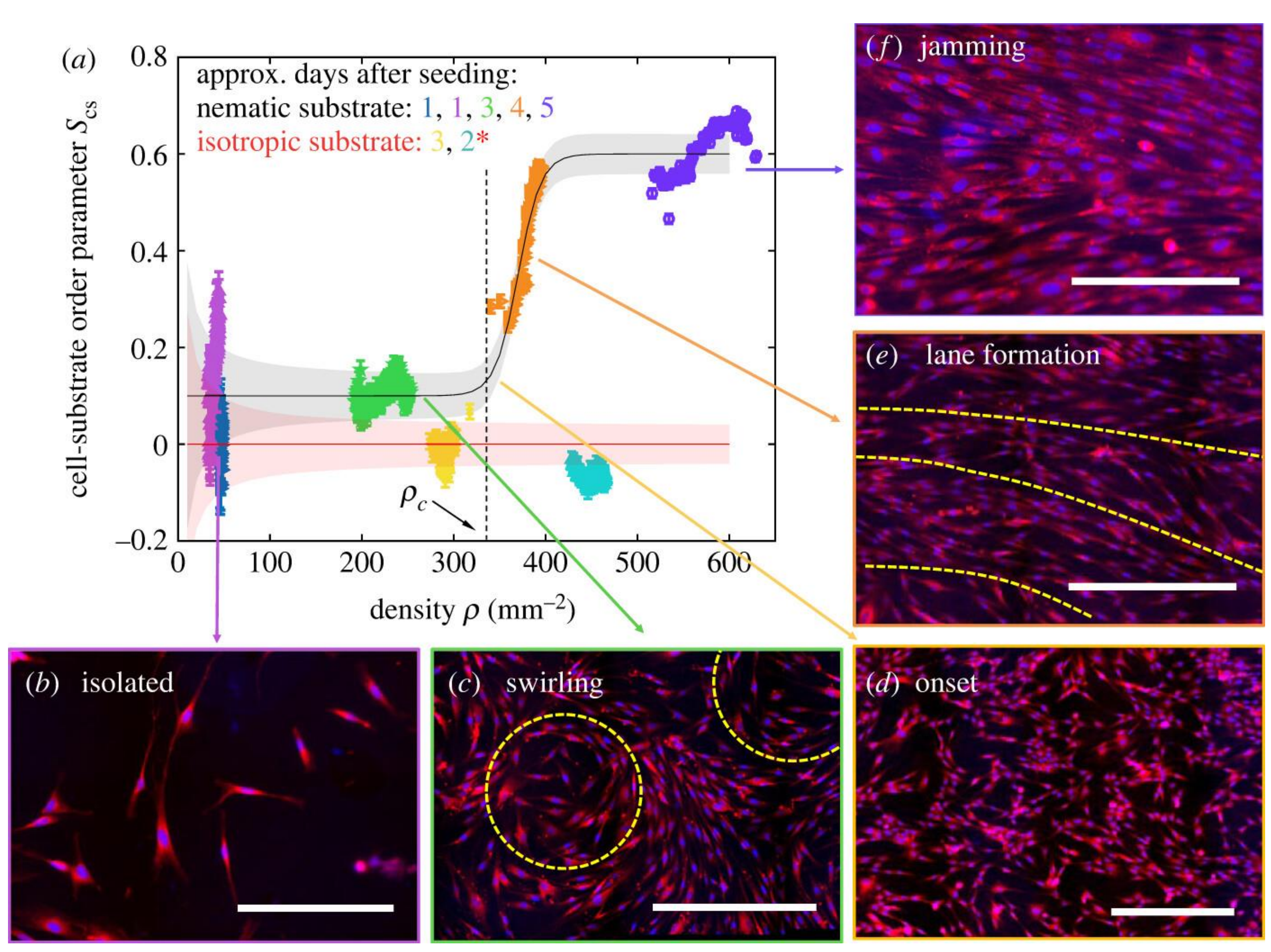
Abstract

Apolar elongated cells growing on an aligned liquid crystal elastomer collectively sense the substrate orientation. As cells grow and divide along their long axis, they create locally aligned domains. The ordered domains then grow and align with the substrate. At high densities cells jam and growth ceases. The jamming density depends on the order: Highly aligned cells jam at higher densities. The degree of order of the final state depends on the initial seeding density, with smaller seeding densities leading to more aligned monolayers. We model this as a growing nematic material that aligns to an external field and jams at high number densities. We find that for a range of parameters, initial seeding conditions determine the final order and density of cells on jamming, as seen in experiments.

hDF cells growing on stiff nematic substrate align along the substrate direction



Growing hDFs form density dependent patterns: low-density swirls and high-density lanes



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Model of a Growing Nematic Capable of Jamming, Interacting With an External Field

Nematic state is favoured above a transition density ($\rho_{i\to n}$)
External field aligns in the direction of substrate (Π)
Rotational viscosity increases as system reaches jamming:

$$\partial_t Q_{ij} = -\Gamma_0^{-1}\tanh(\rho_J-\rho)\left[(\rho_{i\to n}-\rho+\rho S^2)Q_{ij}+\Pi\rho P_{ij}\right]$$

$$\partial_t \rho = \rho(\rho_J-\rho)/\rho_J$$

Logistic growth in density

$$\rho_J = \rho_{IJ} + (\rho_{NJ}-\rho_{IJ})S^2$$

Close packing density increases with order

Angular component is quickly aligned in the direction of the external field. We then look at the reduced space of order parameter and density.

$\rho = \rho_J(S)$ is a line of fixed points (FP), where trajectories end

$h(S,\rho)=0$ gives S-nullcline

Stability of FPs given by eigenvalues of Jacobian:

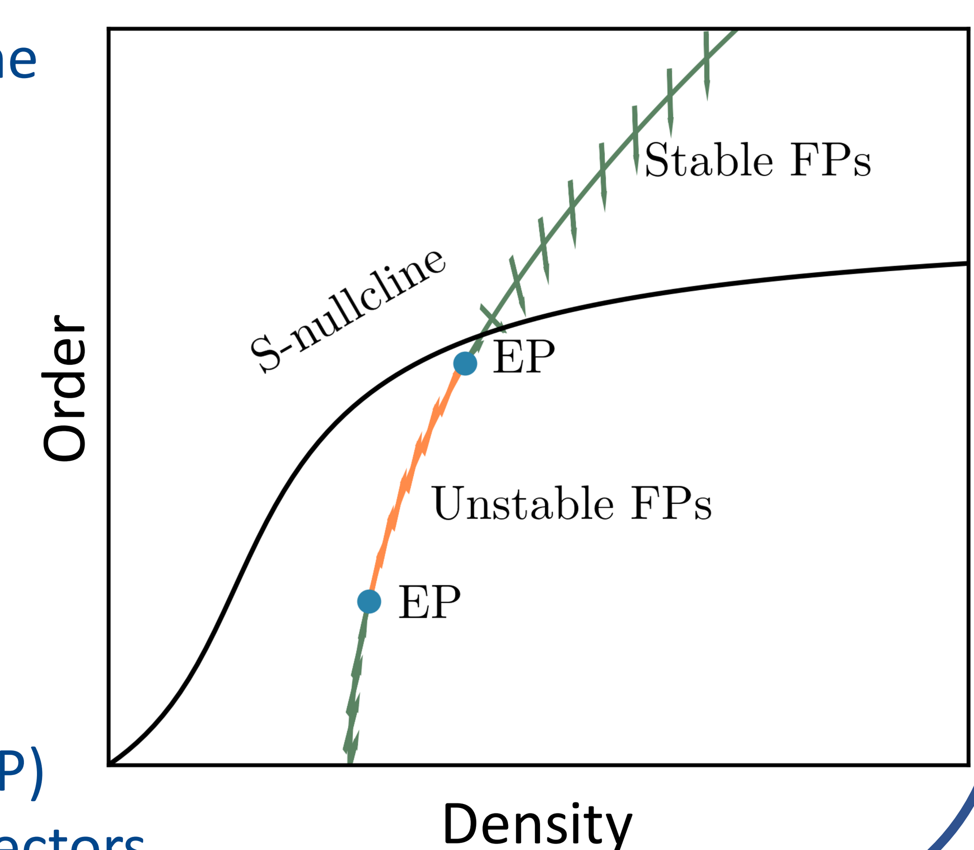
$\lambda_1 = 0$,

Implies tangent eigenvector

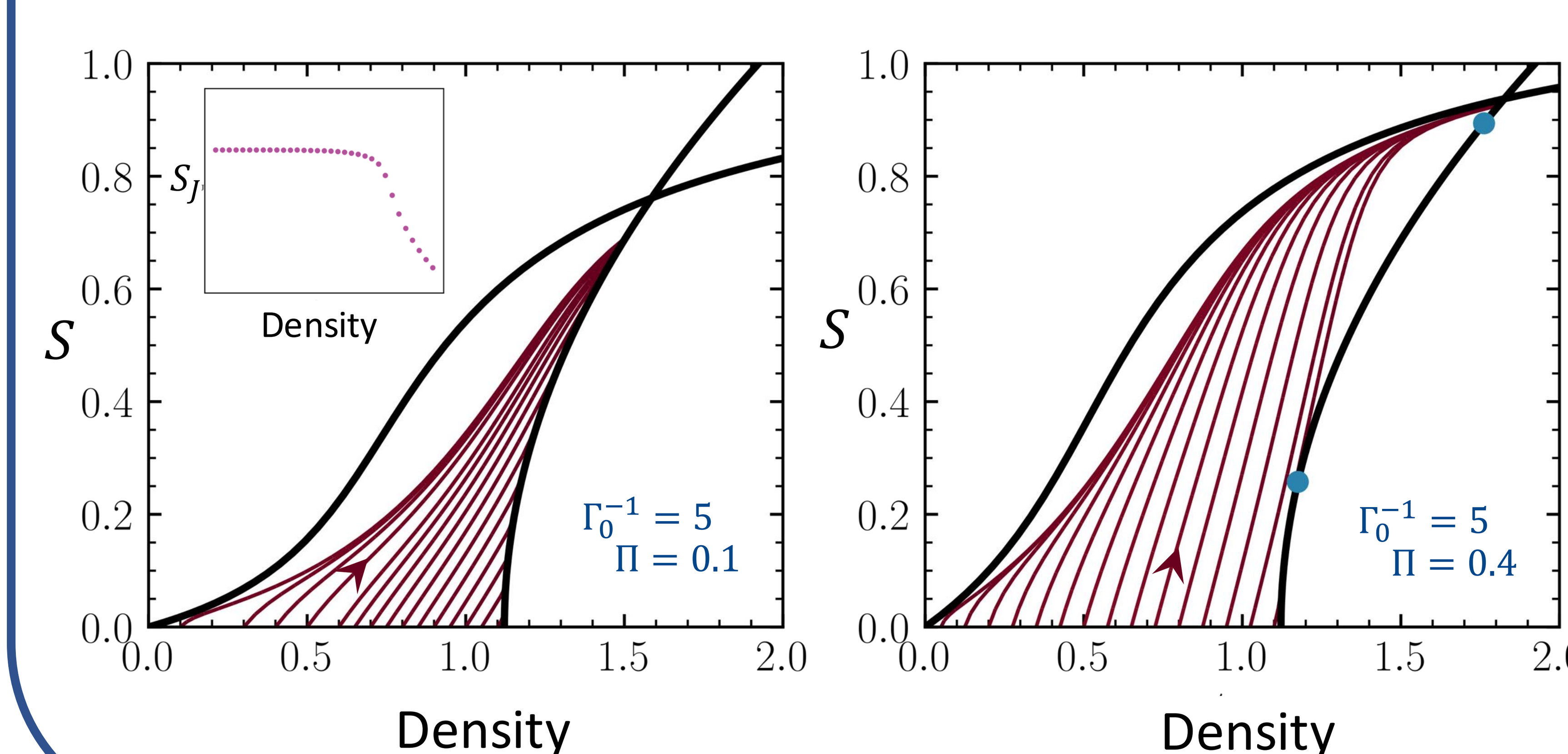
$\lambda_2 = -1 - AS_J\Gamma_0^{-1}h(S_J)$

When $\lambda_2 = 0$,

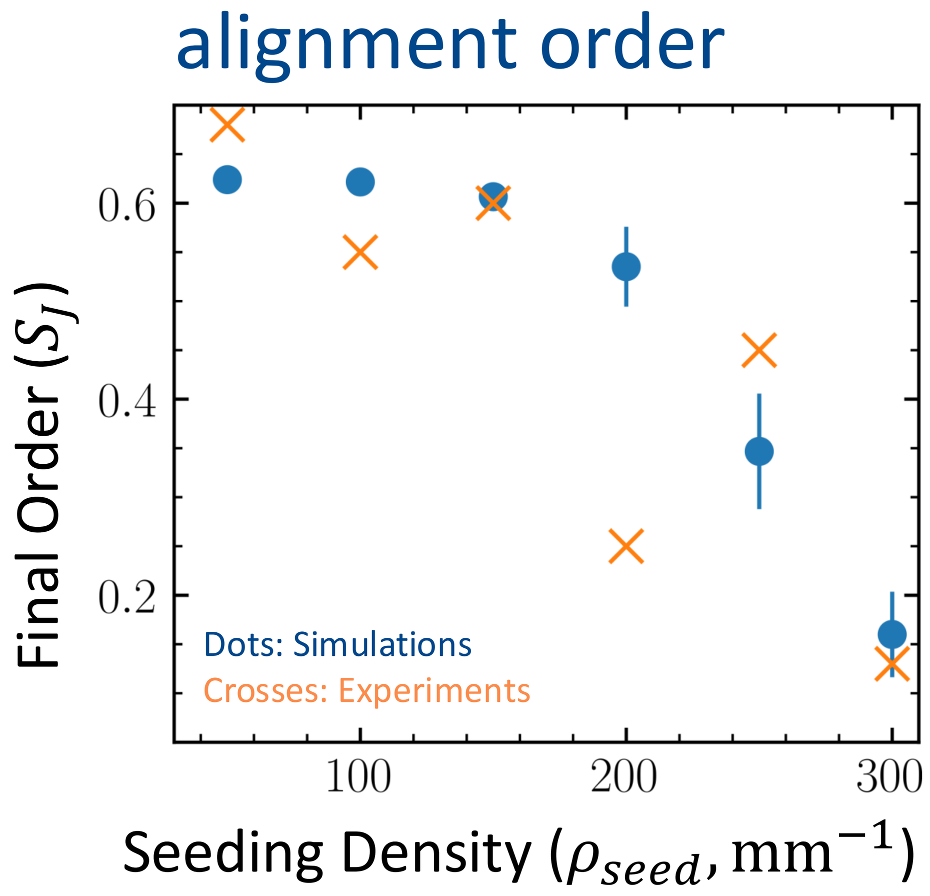
we get Exceptional Point (EP) with overlapping eigenvectors



Order-Density Phase Plots Show Dependence on Seeding Density



Seeding density dictates final cell-cell alignment order



Exceptional Points Trigger Discontinuous Order-Disorder Transition for high ρ_{seed}