Pulsating Active Matter

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We reveal that the mechanical pulsation of locally synchronized particles is a generic route to propagate deformation waves. We consider a model of dense repulsive particles whose activity drives periodic change in size of each individual. The dynamics is inspired by biological tissues where cells consume fuel to sustain active deformation. We show that the competition between repulsion and synchronization triggers an instability which promotes a wealth of dynamical patterns, ranging from spiral waves to defect turbulence. We identify the mechanisms underlying the emergence of patterns, and characterize the corresponding transitions. By coarse-graining the dynamics, we propose a hydrodynamic description of an assembly of pulsating particles, and discuss an analogy with reaction-diffusion systems.

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$$\dot{\mathrm{r}}_i = -\mu \sum_j \partial_{\mathrm{r}_i} U\left(a_{ij}\right) + \sqrt{2D}\xi_i$$

$$a_{ij} = \frac{\left|\mathrm{r}_i - \mathrm{r}_j\right|}{\sigma\left(\theta_i\right) + \sigma\left(\theta_j\right)}$$

$$\sigma\left(\theta_i\right) = \sigma_0 \frac{1 + \lambda \sin\theta_i}{1 + \lambda}$$

$$U(a) = \begin{cases} U_0\left(a^{-12} - 2a^{-6}\right), & a < 1 \\ 0, & \text{otherwise} \end{cases}$$

Symbols	Meanings
r	position
θ	phase, determining the particle size
U	pairwise repulsive potential
μ	self-propulsion mobility
D	diffusivity
ξ	isotropic Gaussian white noise
$\sigma(\theta)$	particle size
σ_0	largest size
$\lambda < 1$	pulsation amplitude

$$\dot{\theta}_i = \omega - \sum_j \left[\tau\left(a_{ij}, \theta_i - \theta_j\right) + \mu_\theta \partial_{\theta_i} U\left(a_{ij}\right)\right] + \sqrt{2D_\theta}\eta_i$$

$$\tau(a, \theta) = \begin{cases} \varepsilon \sin(\theta), & a < 1 \\ 0, & \text{otherwise} \end{cases}$$