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Weak synchronization and large-scale collective oscillation in dense bacterial suspensions[1]

YILIN WU, The Chinese University of Hong Kong

Collective oscillatory behavior is ubiquitous in nature and it plays a vital role in many biological processes. Collective oscillations in biological multicellular systems often arise from coupling mediated by diffusive chemicals, by electrochemical mechanisms, or by biomechanical interaction between cells and their physical environment. In these examples, the phase of some oscillatory intracellular degree of freedom is synchronized. Here, in contrast, we discovered a unique 'weak synchronization' mechanism that does not require long-range coupling, nor even inherent oscillation of individual cells: We found that millions of motile cells in dense bacterial suspensions can self-organize into highly robust collective oscillatory motion, while individuals move in an erratic manner. Over large spatial scales we found that the phase of the oscillations is in fact organized into a centimeter scale traveling wave. We present a model of noisy self-propelled particles with strictly local interactions that accounts faithfully for our observations. These findings expand our knowledge of biological self-organization and reveal a new type of long-range order in active matter systems. The mechanism of collective oscillation uncovered here may inspire new strategies to control the self-organization of active matter and swarming robots.

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