Non-equilibrium transition in self-propelled particle array mediated through hydrodynamic interactions

Wei Yen Woon[1], Yi-Teng Hsiao[1], Kuan-Ting Wu[1], Nariya Uchida[2]

1) Department of Physics, National Central University, Jungli 32054, Taiwan
2) Department of Physics, Tohoku University, Sendai, 980-8578, Japan

Collective flow dynamics across a bacterial carpet are investigated through optical tweezers-microsphere assay implemented with a sensitive back-scattered detection method. Attractive vertical forces are detected across bacterial carpets consisting of mutant uni-polarly flagellated *Vibrio alginolyticus* cells. As we increase the rotation frequency of flagella via Na^+ concentration, the collective flow exhibits abrupt increase, suggesting transition to an ordered state with tens of flagella rotating in coordination. The effects of impurities on the collective flow dynamics are examined by uniformly mixing wild type cells with bimodal flagellar rotations in the carpet. For dilute impurities, the transition point is shifted toward higher Na^+ concentration, while the collective force is not affected by the impurities ratio, suggesting an entrainment effect of the flagellar rotation into uniform (counter-clockwise) direction. Increasing the impurities ratio to over 0.25 leads to significant drop in force plateau and susceptibility as well as more gradual transition curves, suggesting partial synchronization with smaller correlation length. The two types of transitions are interpreted as thermally-induced and disorder-controlled transitions, and resemble theoretical predictions on hydrodynamic synchronization in self-propelled rotor arrays.