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Macroscopic model of self-propelled bacteria swarming with regular reversals

Periodic reversals of the direction of motion in systems of self-propelled rod shaped bacteria enable them to effectively resolve traffic jams formed during swarming and maximize their swarming rate. In this paper, a connection is found between a microscopic one dimensional cell-based stochastic model of reversing non-overlapping bacteria and a macroscopic non-linear diffusion equation describing dynamics of the cellular density. Boltzmann-Matano analysis is used to determine the nonlinear diffusion equation corresponding to the specific reversal frequency. Macroscopically (ensemble-vise) averaged stochastic dynamics is shown to be in a very good agreement with the numerical solutions of the nonlinear diffusion equation. Critical density p_0 is obtained such that nonlinear diffusion is strongly suppressed for $p < p_0$. An analytical approximation of the pairwise collision time and semi-analytical fit for the total jam time per reversal period are also obtained. It is shown that cell populations with high reversal frequencies are able to spread out effectively at high densities. If the cells rarely reverse then they are able to spread out at lower densities but are less efficient to spread out at higher densities.