Collective stop-and-go dynamics of active bacteria swarms

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We set up an active macroscopic model of bacterial growth and transport based on a dynamic preferred direction—the collective velocity of the bacteria [1] as opposed to the customary static preferred direction (e.g., the director of an active nematic LC). This collective velocity is subject to the isotropic-nematic transition modeling the density-controlled transformation between immotile and motile bacterial states. The choice of the dynamic preferred direction introduces a distinctive coupling of orientational ordering and transport not encountered otherwise. Our model captures various aspects of the experimental results described by Matsushita and co-workers for the bacterium Proteus mirabilis [2]. In particular, it exhibits a robust pulsating dynamics of a collective stop-and-go type presented in detail in Ref. [3], where it is confirmed that the pulsing is not due to biological (internal clock of the bacteria) or chemical (chemotaxis) factors, but is inherent to the growth and transport dynamics. The inclusion of chirality in the model results in a complex pulsating dynamics.

The approach can also be applied to other systems spontaneously switching between individual (disordered) and collective (ordered) behavior and/or collectively responding to density variations, e.g., bird flocks, fish schools, etc. For example, the preferred direction in a bird flock or a swarm of insects is certainly dynamic and does not exist statically. This unconventional choice introduces a distinctive coupling of orientational ordering and transport not encountered in active systems described by a static preferred direction. Moreover, by using a dynamic preferred direction one can describe collective orientational ordering also in systems that, statically, possess no microscopic direction at all (e.g., a driven system of spherical objects). We think that with its natural application to other systems besides the one presented here, it could also become generic.

References:

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