Contribution ID : **80** Type : **not specified**

Microbial billiards

Thursday, 12 June 2025 11:30 (30)

Unlike gas molecules at equilibrium, the spatial organization of self-propelled particles can be very sensitive to what happens at the boundaries of their container. Understanding the link between boundary phenomena and bulk stationary distributions could enable the design of optimized con- tainer shapes for the geometric control of confined active particles. Here we propose a boundary method based on the flux transfer formalism typical of radiometry problems, where surface ele- ments transmit and receive "rays" of active particles with infinite persistence length. We demon- strate the power of this boundary method in the case of the swimming microalgae Euglena gracilis trapped in light-defined billiard geometries. Leveraging our boundary method, we were able to design a stacked multi-stage billiard geometry, with a connection scheme between subunits that breaks spatial symmetry and achieves an exponential amplification of cell concentration between its two ends. Surprisingly, the sensitive dependence on boundary geometry observed in closed microbial billiards stands in marked contrast to the robust invariance of mean path lengths traced by E.coli bacteria swimming in microfabricated open billiards with frozen internal disorder.

Role

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Session Classification : Session 5