Holographic Imaging Reveals the Mechanism of Wall Entrapment in Swimming Bacteria

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Self-propelled particles, both biological and synthetic, are stably trapped by walls and develop high concentration peaks over bounding surfaces. In swimming bacteria, like E. coli, the physical mechanism behind wall entrapment is an intricate mixture of hydrodynamic and steric interactions with a strongly anisotropic character. The building of a clear physical picture of this phenomenon demands direct and full three-dimensional experimental observations of individual wall entrapment events. Here, we demonstrate that, by using a combination of three-axis holographic microscopy and optical tweezers, it is possible to obtain volumetric reconstructions of individual E. coli cells that are sequentially released at a controlled distance and angle from a flat solid wall. We find that hydrodynamic couplings can slow down the cell before collision, but reorientation only occurs while the cell is in constant contact with the wall. In the trapped state, all cells swim with the average body axis pointing into the surface. The amplitude of this pitch angle is anticorrelated to the amplitude of wobbling, thus indicating that entrapment is dominated by near-field couplings between the cell body and the wall. Our approach opens the way to three-dimensional quantitative studies of a broad range of fast dynamical processes in motile bacteria and eukaryotic cells.