Spatially-controlled activity of light-driven bacteria

Vincent A. Martinez

SUPA and School of Physics & Astronomy, The University of Edinburgh, Edinburgh EH9 3FD, UK

Active matter is a burgeoning field of interdisciplinary endeavour. Suspensions of swimming bacteria, such as *Escherichia coli*, are widely used as model active colloids [1], but a real-time tuneable control of their swimming speed is lacking. Recently, *E. coli* has been genetically modified to swim only when illuminated with green light [2], potentially giving biological active colloids with a wide range of tuneable speed *v*.

We studied several mutants of *E. coli* for which their swimming speed can be controlled by the intensity of incident green light and we specially engineered mutants, which adjust their speed rapidly in response to changes in intensity. By projecting intensity patterns of light onto a suspension of such bacteria we are then able to spatially control the activity of these suspensions over large length-scales (~ 1 mm) and create dynamic or static complex structure (see Figure).

It has been predicted theoretically that swimmer density is inversely proportional to swimming speed [3]. Whether this applies to swimming bacteria is investigated here. We developed Differential Dynamic Microscopy to spatially resolve the activity of such suspensions. This allows us to extract key parameters, e.g. swimming speed *v*, relative change in local cell density ρ/ρ_0 and the fraction of non-motile cells β over large length-scales. Providing suitable experimental conditions, we confirm the theoretical prediction.

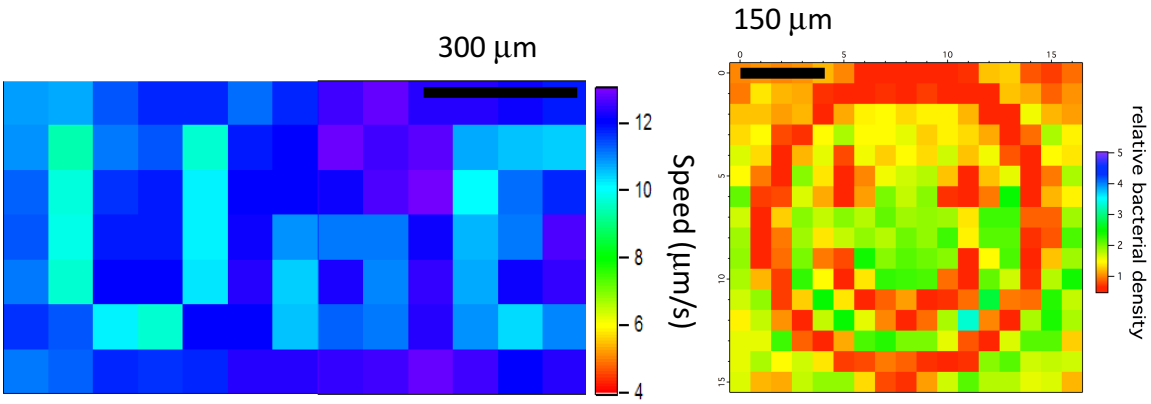

Figure: Examples of spatial control of bacterial swimming speed (Left) and density (right).

1. Schwarz-Linek J, Arlt J, Jepson A, Dawson A, Vissers T, Miroli D, Pilizota T, Martinez VA, Poon WCK. Escherichia coli as a model active colloid: A practical introduction. *Colloids Surfaces B Biointerfaces* **137,** 2–16 (2016).
2. Walter JM, Greenfield D, Bustamante C, Liphardt J, Light-powering Escherichia coli with proteorhodopsin. *Proc. Natl. Acad. Sci.* **104,** 2408–12 (2007).
3. Tailleur J & Cates ME, Statistical Mechanics of Interacting Run-and-Tumble Bacteria. *Phys. Rev. Lett.* **100,** 3–6 (2008).