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Measuring oscillatory velocity fields due to swimming algae

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Single cells exhibit a diverse array of swimming strategies at low Reynolds number to search for nutrients, light, and other organisms. The fluid flows generated by their locomotion are important to understanding biomixing and interactions between cells in suspension. In the accompanying video (and supplementary material), we show that even the most common of propulsion mechanisms can result in surprisingly complex hydrodynamics. In particular, we study the oscillatory flows produced by the biflagellated green alga *Chlamydomonas reinhardtii*, which swims with a mean speed of 130 \( \mu \text{m/s} \) by beating its flagella with specific wave forms at 50 Hz.

The 8 \( \mu \text{m} \) unicellular microorganisms are confined to a 15 \( \mu \text{m} \) thin free-standing liquid film, which creates a quasi-two-dimensional environment for clear observation, and 1 \( \mu \text{m} \) particles are added to the cell suspension as flow tracers. The cells and tracers are tracked simultaneously using high-speed video microscopy (500 fps, 40 \( \times \)) to measure the instantaneous velocity fields generated during the beat cycle of the cells (20 ms period).

FIG. 1. (Color) Velocity field time series during the beat cycle of the biflagellate *C. reinhardtii* (black disc, swimming to the right) measured by particle tracking in a thin fluid film. The hyperbolic stagnation point is shown (green \( \bullet \)), and insets depict the beat cycle phase (lower left) and the instantaneous flagellar conformation (lower right). Reprinted with permission from J. S. Guasto, K. A. Johnson, and J. P. Gollub, Phys. Rev. Lett. 105, 168102 (2010); Copyright 2010, American Physical Society (Ref. 1) (enhanced online) [URL: http://dx.doi.org/10.1063/1.3640006.1].