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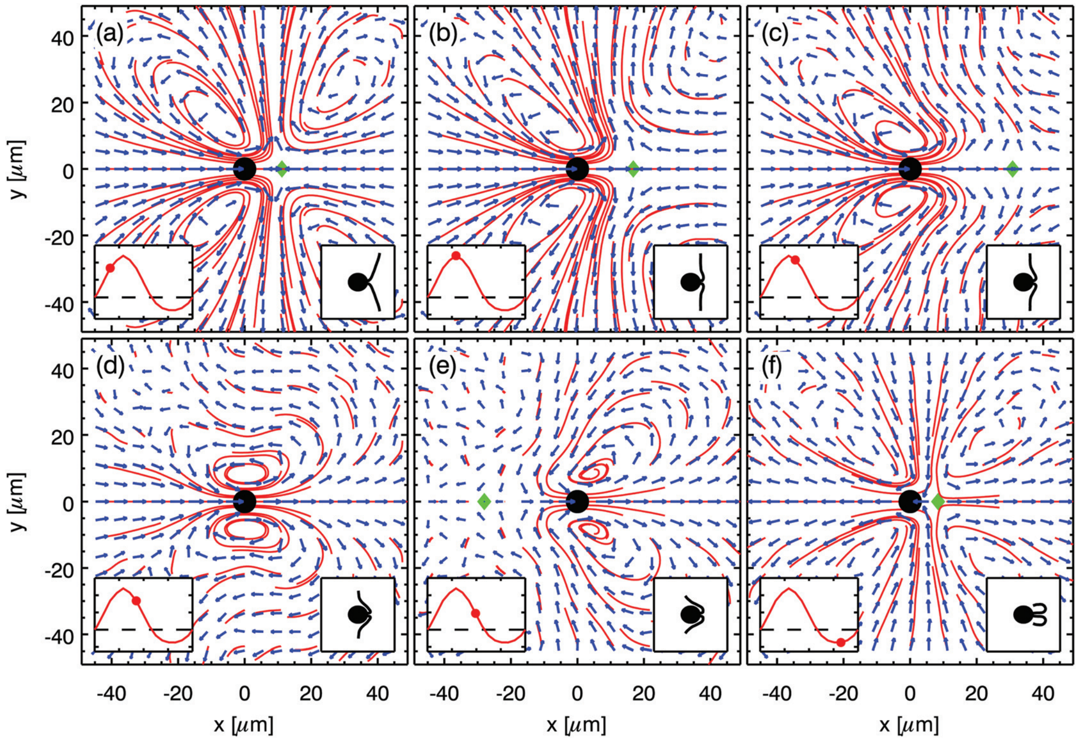

FIG. 1. (Color) Velocity field time series during the beat cycle of the biflagellate *C. reinhardtii* (black disc, swimming to the right) measured by particle tracking in a thin fluid film. The hyperbolic stagnation point is shown (green ◆), and insets depict the beat cycle phase (lower left) and the 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].

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 μm/s by beating its flagella with specific wave forms at 50 Hz.

The 8 μm unicellular microorganisms are confined to a 15 μm thin free-standing liquid film, which creates a quasi-two-dimensional environment for clear observation, and 1 μm 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×) to measure the instantaneous velocity fields generated during the beat cycle of the cells (20 ms period).[1] Figure 1 shows a time series of the flow field with instantaneous streamlines (red) and velocity vectors (blue, log scale), with the cell always shown at the center of the diagram, moving to the right.

Early in the power stroke, the velocity field resembles a force dipole, which differs significantly from the time-averaged flow field over the beat cycle[1,2] [Fig. 1(a)]. The peak of the power stroke occurs when the flagella are extended perpendicular to the swimming direction [Fig. 1(b)]. As the power stroke is completed, the vortices posterior to the organism shift toward the anterior [Figs. 1(c)–1(e)]. At the peak of the recovery stroke, the flow field is again reminiscent of a dipole, but with opposite sign [Fig. 1(f)], before the cycle begins again. Such measurements of cell-generated flows are an important step in understanding the mechanics of single cells and the transport properties of active media. This work was supported by NSF Grant DMR-0803153.

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