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Energy-optimal phase control of unsteady fluid flows ADITYA NAIR, University of Washington, KUNIHIKO TAIRA, University of California, Los Angeles, BINGNI BRUNTON, STEVEN BRUNTON, University of Washington — Controlling the phase of oscillation of unsteady fluid flows is crucial in terms of advancing and delaying flow field characteristics. Our goal is to design an optimal flow control strategy that alters the oscillation phase in fluid flows using minimum energy input. We perform a phase reduction analysis to construct a reduced-order model in terms of a phase-sensitivity function that tracks the phase of oscillation in response to impulse perturbations. Using the phase sensitivity function and its gradient, the optimal control law is obtained by solving the Euler-Lagrange equations as a two-point boundary value problem. We demonstrate the approach for incompressible flow over a cylinder at low Reynolds number and discuss extensions to complex flows. Multiple actuation strategies based on blowing and rotary control are also explored. Finally, we examine the synchronization and desynchronization properties of the optimally controlled flow and discuss broader implications for flow control.

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