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Lagrangian studies of animal swimming and aquatic predator-prey interactions[1]

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Experimental studies of animal swimming have been traditionally based on an Eulerian perspective in which the time-dependent flow field surrounding the animal is measured at fixed locations in space. The measured velocity field and its derivatives (e.g. vorticity) can, in principle, be used to deduce the forces, energetics, and fluid transport associated with locomotion in real fluids. However, achieving a connection between measurements of these Eulerian fields and the dynamics of locomotion has proven difficult in practice. We present the application of Lagrangian methods of flow analysis in which the time-dependent trajectories of individual tracer particles in the flow are measured experimentally and subsequently interrogated using dynamical systems tools in order to quantitatively resolve the dynamics of animal swimming. The Lagrangian methods are shown to be readily extended to time-dependent measurements in three spatial dimensions and to in situ field measurements using a recently developed self-contained underwater velocimetry apparatus (SCUVA). Case studies of jellyfish and other aquatic animals observed in the laboratory and in marine environments are used to illustrate the proposed approach. We also show that predator-prey interactions during jellyfish swimming can be addressed using the aforementioned Lagrangian methods in combination with the Maxey-Riley equations for inertial particles in fluid flow.

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