HAMILTONIAN MODELS FOR THE COUPLED DYNAMICS OF VORTICES AND NEUTRALLY BUOYANT RIGID BODIES

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The talk will focus on the dynamics of vorticity and vortical structures interacting with moving neutrally buoyant rigid bodies in ideal flows of Newtonian fluids examined in the framework of geometric mechanics. Beginning with a brief review of the ideas set forth by Arnold (’66), Marsden and Weinstein (’83), Morrison (’82) (among others) on how vorticity fields in unbounded domains can be viewed as generalized momenta and the Euler equations as symmetry reduced equations, I will then talk about ongoing attempts to extend this framework to the case where there is a moving neutrally buoyant rigid body in the flow. Apart from `scientific curiosity’, the motivations come from locomotion problems in nature and engineering such as fish swimming, design of small autonomous underwater/aerial vehicles etc., where the dynamic interaction of coherent vortical structures with the neutrally buoyant body is considered important for the efficient momentum transfer to and maneuverability of the moving body. Hamiltonian formulation for special configurations where the vorticity is modeled as discrete structures, such as point vortices, vortex rings, will be discussed in detail. For a simple circular body geometry in the plane, some results on bifurcations and control of the system will also be presented. Finally, in an attempt to connect to real flows, a movie on experiments done by my late colleague James Allen with a neutrally buoyant sphere and a vortex ring in a water channel will be shown.