Some new aspects of three-sphere swimmers

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First, we discuss the locomotion of a three-sphere microswimmer [1] in a viscoelastic mediumand propose a new type of active microrheology [2]. We derive a relation that connects the average swimming velocity and the frequency-dependent viscosity of the surrounding medium. In this relation, the viscous contribution can exist only when the time-reversal symmetry is broken, whereas the elastic contribution is present only when the structural symmetry of the swimmer is broken. Purcell's scallop theorem breaks down for a three-sphere swimmer in a viscoelastic medium.

Next, we discuss the dynamics of a generalized three-sphere microswimmer in which the spheres are connected by two elastic springs [3]. The natural length of each spring is assumed to undergo a prescribed cyclic change. We analytically obtain the average swimming velocity as a function of the frequency of cyclic change in the natural length. In the low-frequency region, the swimming velocity increases with frequency, and its expression reduces to that of the original three-sphere model by Najafi and Golestanian. Conversely, in the high-frequency region, the average velocity decreases with increasing frequency. Such behavior originates from the intrinsic spring relaxation dynamics of an elastic swimmer moving in a viscous fluid.

Finally, we discuss the directional motion of an elastic three-sphere micromachine in which the spheres are in equilibrium with independent heat baths having different temperatures (see Fig.1) [4]. Even in the absence of prescribed motion of the springs, such a micromachine can gain a net motion due purely to thermal fluctuations. A relation connecting the average velocity and the temperatures of the spheres is analytically obtained. This velocity can also be expressed in terms of average heat flows in the steady state. Our model suggests a new mechanism for locomotion of micromachines in nonequilibrium biological systems.

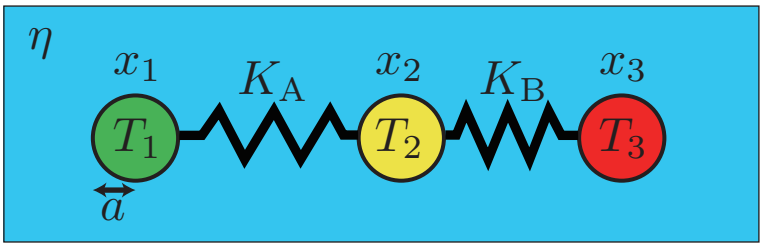

Fig.1: Thermally driven elastic three-sphere micromachine in a viscous fluid.

References

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