The Role of Thermal Fluctuations in the Motion of Free Bodies: Viscoelasticity vs. Orientational Diffusion

Jaime Arturo de la Torre[1, S, C], Pep Español[1] and Mark Thachuk[2]

[1]*Dept. Física Fundamental UNED, Madrid, Spain*
[2]*Department of Chemistry, University of British Columbia, Vancouver, Canada, Vancouver, Canada*
jatorre@fisfun.uned.es

In this work, we present a non-equilibrium, first-principles, statistical mechanics derivation of Euler's equations from Hamilton's equations of the constituent particles of a body. This allows us to generalize the usual equations of a rigid body to the case where deformation, dissipation, and thermal fluctuations are present. This fills, for the first time, the gap between Euler's rigid body equations and Hamilton's equations for the constituent particles of the body. Euler's equations appear as the reversible part of a coarse-grained theory that takes as relevant variables the shape (through principal moments) and the orientation of the body.

This work shows that there are two distinct dissipative mechanisms in a real body. One is viscoelasticity, the effect of which is to relax the shape of the rotating body towards its equilibrium shape. This effect has traditionally been identified as responsible for the fact that rotating free bodies, like asteroids, are in the vast majority in pure rotation around the major axis. We show that in the present theory, the actual mechanism of alignment is orientational diffusion, a new process that has not been described before. The mechanism is behind the counterintuitive fact that a non-spinning molecule (with zero angular momentum) explores all its possible orientations, according to the uniform Haar measure.

References

1. Español, P., Thachuk, M., & de la Torre, J. A. (2023). The role of thermal fluctuations in the motion of a free body. *arXiv preprint* arXiv:2303.15295.