Molecular motors and Brownian time crystals

Antti Niemi
Nordita, Sweden

Falling cats have a remarkable ability to turn in midair and land safely on their feet, even without angular momentum. The phenomenon can be explained using the mathematical framework of a connection in shape space. In this talk we argue that this connection can also explain the exceptional performance of many biomolecular motors. It organizes the thermal vibrations of individual atoms into a coordinated rotational motion of the entire molecule, enabling the molecule to evade the conclusions of Feynman's ratchet-and-pawl analysis. First, we present two molecular models that exemplify how universal directed rotational motion emerges from shape changes, even without angular momentum. We then implement an all-atom design approach for knotted polyalanine ring molecules, and find the emergence of a cooperative rotational organization of individual atom thermal vibrations that is dictated by the connection. Our molecular dynamics simulations also expose the dynamical consequences of spontaneous symmetry breakdown. The rotational motion arises so effortlessly even in ambient water, such that the molecule can be described using an effective theory time crystal.