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Probing the Stochastic Properties of DNA Driven by Topology-relaxing Enzyme Activity

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DNA topology-relaxing enzymes in the cell nucleus produce simplified topology, allowing entangled duplex DNA strands to pass one through another, essential for many critical cell nuclear processes including successful DNA segregation during cell division. Here, we carry out 1-point and 2-point microrheology on a model system of DNA at physiologically-relevant concentrations with and without enzyme activity of topoisomerase II. We find that the aggregate, incoherent effect of the enzyme activity creates randomly fluctuating forces, which drive diffusive-like, non-thermal motion. We combine these measurements of random motion with independent micro mechanical measurements and show that the enzyme-driven fluctuations are quantitatively consistent with $1/f$ noise, far from what is expected for thermal motion, and of a completely different 'colour' from non-equilibrium fluctuations in the cytoplasm driven by processive cytoskeleton motors. Our measurements at different energy fluxes could shed light on the connection between the enzyme's maintenance of the system away from thermodynamic equilibrium and its simplification of topology over large length scales so key to enhancing nuclear transport for many processes.

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