It's not only sequence-specific DNA-binding proteins that have figured out how to read the electrostatic potential of the minor groove. Rohs *et al.*[1] show that histone octamers, the protein complexes around which DNA wraps to form nucleosomes, also exploit this mechanism. By comparing nucleotide sequences of DNA segments known to form nucleosomes, they show that short A-tracts have a tendency to be periodically spaced throughout such sequences. They also find, from X-ray structures of nucleosomes, that arginines are often present in the minor groove where it narrows as a consequence of wrapping the DNA double helix around the histone octamer.

The ability to sense the variation in electrostatic potential in DNA may reveal how a protein could home in on its binding site in the genome without touching every nucleotide, as electrostatics is a through-space phenomenon. A difficulty of applying the analysis presented in this study is that it depends on high-resolution three-dimensional structures of protein–DNA complexes — that's the necessary input to the Poisson–Boltzmann equation that was used by Rohs *et al.*[1] to calculate the electrostatic potential of the minor groove. If we could develop an experimental measure of the minor-groove potential and how it varies with sequence, it would be possible to read the human genome like a protein does, treating DNA as a molecule and not just a string of letters. ■

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STATISTICAL PHYSICS

Swirled by light

Mark I. Dykman

A micrometre-sized particle immersed in a liquid can be trapped by light. An experiment shows that the trapping can be accompanied by a whirling whose direction can be reversed by changing the light intensity.

The past few decades have witnessed remarkable progress in the control and manipulation of tiny objects, including micrometre-sized particles, bacteria and DNA molecules. These advances are associated with the development of optical tweezers[1,2] — instruments that use strongly focused laser light to trap objects and move them at will. However, the stiffness of optical tweezers is limited, and an optically trapped particle does not reside at the trap centre but rather wanders about it. Such wandering is a consequence of thermal fluctuations in the particle's surrounding liquid, and is a counterpart of the random motion experienced by free-floating particles — the Brownian motion explained by Albert Einstein in 1905.

Writing in *Physical Review E*, Sun *et al.*[3] report that the trajectory of an optically trapped colloidal particle in water, although random, can display a complicated but identifiable pattern. The particle's motion is characterized by a circulatory bias — the streamlines that are obtained by averaging over an ensemble of trajectories exhibit circulation. The authors associate this circulation with a toroidal particle current and call it a Brownian vortex. Interestingly, they find that the overall streamline pattern and the direction of the circulation depend on the intensity of the laser light used to trap the particle, with the possible coexistence of counter-rotating rolls of toroidal current. (A spurious inward spiralling in the streamline pattern was addressed by the authors in an independent study[4].)

Sun and colleagues' observation[3] of a macroscopic flux — in the form of streamline circulation — is both interesting in itself and a clear indication that the particle is not at thermal equilibrium. The flux was found in a stationary optical trap, in contrast to the directed motion of Brownian particles seen previously[5] in non-stationary traps, in which a ratchet-like optical potential was periodically modulated in time.

The absence of macroscopic fluxes is a fundamental property of classical systems in thermal equilibrium. Such fluxes would dissipate energy through some form of friction, and would decay if there was no energy input from the outside. By contrast, non-equilibrium systems that gain energy from external sources should generally display fluxes. These fluxes can be stationary — a property compatible with the system as a whole being stationary (with no accumulation of particles, energy and so on) and with the probability distribution of its dynamical variables being independent of time. For optically trapped, transparent colloidal particles in thermal equilibrium, the stationary probability distribution has been studied in detail[6,7].

Non-equilibrium, flux-carrying systems can be divided into two classes. One comprises systems characterized by a stationary flux that is sustained by a periodic or constant external driving and does not require fluctuations (thermal or non-thermal) to persist. A well-known physical example of such a system is a laser: once a laser starts radiating in response to external pumping, the primary effect of fluctuations is to reduce the coherence of the laser radiation — that is, the extent to which the emitted laser light waves are in step with one another decreases. By contrast, in systems belonging to the second class, external driving on its own cannot support a stationary flux; the very occurrence of the flux is due to fluctuations[8]. It is into this second category that the colloidal-particle system studied by Sun and colleagues[3] falls.

An insight into the onset of a fluctuation-facilitated flux can be gained by looking at the fluctuation dynamics of a system. In the 1950s, Onsager and Machlup noticed[9] that, for a colloidal particle in thermal equilibrium, the most likely trajectory from the equilibrium position to a given spatial point coincides with the time-reversed most likely path the particle would follow from that point. Therefore, most probably, the particle arrives at a point with a velocity opposite to the one with which it leaves the point. The implication is that there is no net flux. By contrast, the most probable trajectories of non-equilibrium systems, such as that studied by Sun *et al.*[3], lack time-reversal symmetry, and this leads to the onset of a flux. That there is a difference between the most probable trajectories of a non-equilibrium system to and from a given point has been demonstrated both in analogue electrical circuits[10] and experimentally[11].

Sun and colleagues' observation[3] of a stationary flux and its intricate structure for an optically trapped colloidal particle provides insight into the physics of systems away from thermal equilibrium, demonstrating features in their dynamical behaviour that have no analogue in systems in thermal equilibrium. The trajectory-based approach is useful for gaining such insight because of its sensitivity to the dynamics of the system. In the context of optical tweezers and their applications, the experiment raises questions about the nature of the forces to which a particle is subjected in an optical trap and the reason the particle is not in thermal equilibrium. ■

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