Master 2 Internship

Title: **Probing Short-Time and Small-Scale Brownian Motion with Optical Traps**
Type: experimental
Supervisor(s): Julien BURGIN
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PhD funding (if any): *We are currently applying for research grants to fund a PhD position (3 years) that will build on this work.*

Project:

Optical trapping was first demonstrated in 1970 with the discovery of radiation pressure forces on dielectric spheres and the pioneering experiments of A. Ashkin (Nobel Prize 2018). Initially applied to cold atoms in the 1990s, optical forces have since become a powerful tool for manipulating and probing matter at the nanoscale throughout the 2000s and 2010s.

Brownian motion, first observed in the early 19th century, has fascinated scientists for more than two centuries. One of the major challenges has been measuring instantaneous velocity, which depends critically on the temporal sampling rate. While x(t) was considered continuous but not differentiable, Einstein argued that instantaneous velocity could never be measured. Remarkably, this was recently achieved in liquids and gases with an optically trapped particle (Rice University, Texas), requiring a spatial resolution of 10 pm and a temporal resolution of 5 ns. These studies reveal the short-time transition from the "diffusive regime" (mean square displacement scaling as t) to the "ballistic regime" (MSD scaling as t^2).

At LOMA, we have developed a unique optical trapping setup combining balanced detection, high-speed acquisition, and an ultra-stable continuous laser. We have already observed the ballistic regime in water and measured particle velocity and its autocorrelation function. Our system achieves state-of-the-art sensitivity, reaching noise levels down to 10^{-15} m/√Hz.

We are now seeking a motivated Master 2 student to take part in this experiment, with opportunities to:

- benchmark noise performance and refine instantaneous velocity measurements,
- optimize and upgrade the detection setup,
- explore Brownian motion near boundaries (rigid wall, soft walls).

The student will join a stimulating, multidisciplinary environment at LOMA, working closely with the EMetBrown group (Thomas Salez, Yacine Amarouchene), NOG group (Julien Burgin, Yann Louyer) and LOMA staff (Théo Guillaume).

Applicants should have a strong interest in experimental physics applied to fundamental problems. Background knowledge in optics, nanoscience, nonlinear physics, or statistical physics will be highly valuable. Programming experience (Python or Matlab) is welcome.