P10 – Inertial effects of a small Brownian particle cause a colored power spectral density of thermal noise

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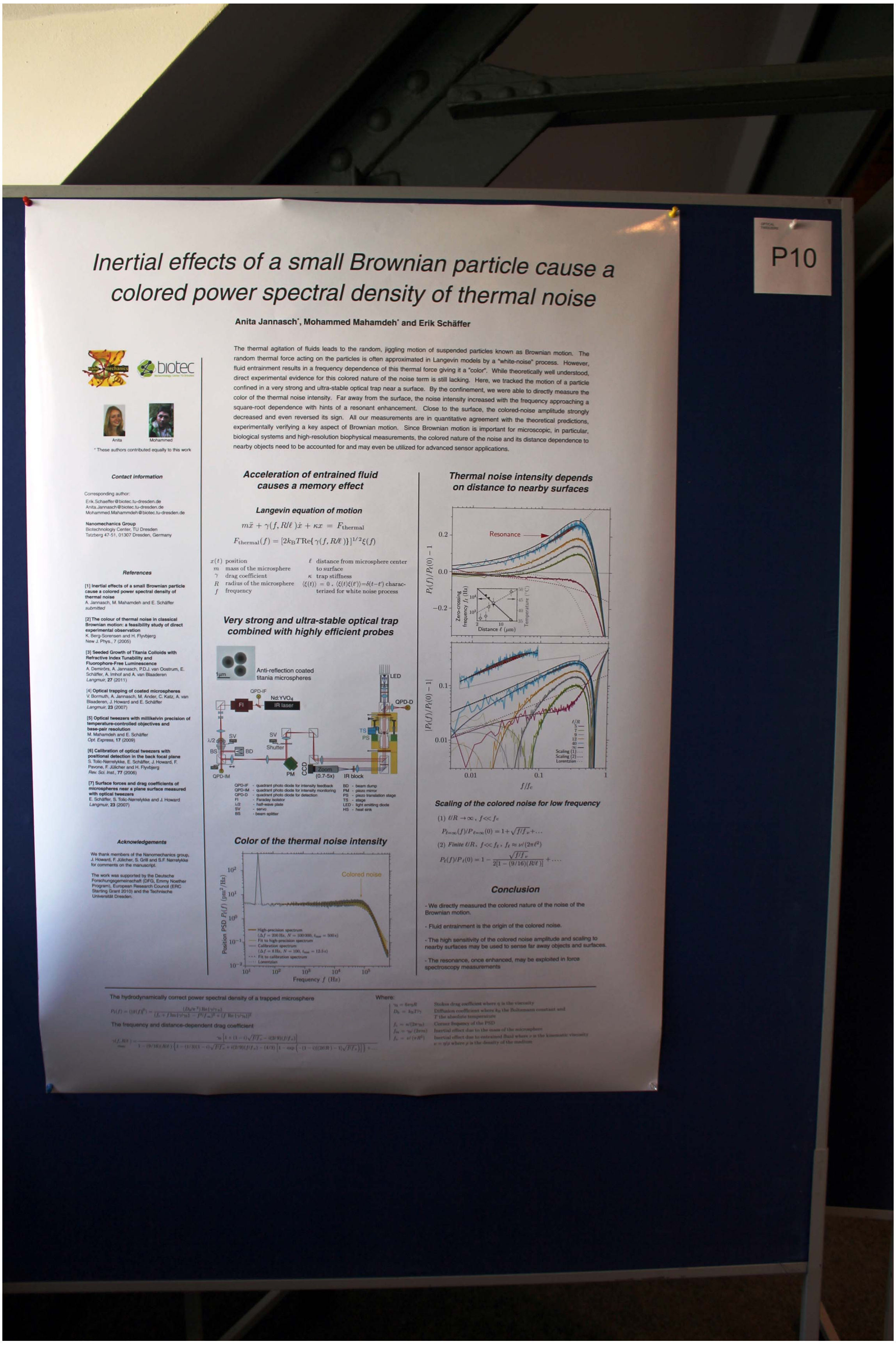
The thermal agitation of fluids leads to the random, jiggling motion of suspended particles known as Brownian motion. The random thermal force acting on the particles is often approximated in Langevin models by a “white-noise” process. However, fluid entrainment results in a frequency dependence of this thermal force giving it a ”color”. While theoretically well understood, direct experimental evidence for this colored nature of the noise term is still lacking. Here, we tracked the motion of a particle confined in a very strong and ultra-stable optical trap near a surface. By the confinement, we were able to directly measure the color of the thermal noise intensity. Far away from the surface, the noise intensity increased with the frequency approaching a square-root dependence with hints of a resonant enhancement. Close to the surface, the colored-noise amplitude strongly decreased and even reversed its sign. All our measurements are in quantitative agreement with the theoretical predictions, experimentally verifying a key aspect of Brownian motion. Since Brownian motion is important for microscopic, in particular, biological systems and high-resolution biophysical measurements, the colored nature of the noise and its distance dependence to nearby objects need to be accounted for and may even be utilized for advanced sensor applications.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Contact information
References
Acknowledgements
Acceleration of entrained fluid causes a memory effect
Langevin equation of motion
Very strong and ultra-stable optical trap combined with highly efficient probes
Anti-reflection coated titania microspheres
Color of the thermal noise intensity
Colored noise
Thermal noise intensity depends on distance to nearby surfaces
Resonance
Scaling of the colored noise for low frequency
Conclusion
- We directly measured the colored nature of the noise of the Brownian motion.
- Fluid entrainment is the origin of the colored noise.
- The high sensitivity of the colored noise amplitude and scaling to nearby surfaces may be used to sense far away objects and surfaces.
- The resonance, once enhanced, may be exploited in force spectroscopy measurements.