Experimental Evidence of Strong Anomalous Diffusion in Living Cells

by Prof. Daphne Weihs

Biomedical Engineering, Technion-Israel Institute of Technology, Haifa, Israel

Abstract:

We show that transport of polymeric particles embedded deep within living cancer cells exhibits strongly anomalous diffusion. The mean square displacement demonstrated super-diffusion with a scaling exponent of 1.25. That indicates active transport of particles in the cell, most likely due to molecular motors, and in accordance with previous studies. To further characterize the transport, we have calculated a range of time-dependent displacement moments. For each moment order q, a scaling exponents $\lambda(q)$ was extracted, such that: $<|r(t+\tau)-r(t)|>^q \sim \tau^{\lambda(q)}$. Scaling exponents were non-linear with q, indicating that the motion is not scale-invariant. In addition, the quantity $\lambda(q)/q$ was non-decreasing, and thus fills the conditions for strong anomalous diffusion, presented here experimentally for the first time. Specifically, scaling exponents exhibited a bi-linear form with moment order, with slopes of ~0.6 at low q-values and ~0.8 at high ones. The bi-linearity indicates that particle motion is composed of sub-diffusive regimes separated by active flights; those were sub-ballistic, by the slope of 0.8, and were not separable using a directionality criterion based on an angle correlation function. We suggest that the sub-ballistic flights are associated with the small particles size used in this work (100-200 nm); small particles diffuse within the cytoplasm while being actively transported, resulting in sub-ballistic motion. Results are further discussed in terms of particle interactions with their microenvironment and dynamics of that environment.

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Room PH 127

Contact:

Prof. Ralf Metzler, metz@ph.tum.de , phone: -12340