A novel model for anomalous transport in biological systems

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Recent advances in experimental methods of single-particle tracking gave rise to challenges in biophysical systems, in particular, in the investigations of bacteria foraging and biological cell transport. These studies proved the presence of strong inhomogeneity in the statistical ensemble of trajectories, thus determining power-law statistics and anomalous diffusion. Anomalous scaling laws are ubiquitous in nature: blinking nanocrystals, light propagation in optical glasses, foraging patterns of animals, epidemic spreading, human travel. Consequently, the understanding and modeling of processes governing anomalous transport is nowadays a crucial task.

Although such models as the Continuous time random walks (CTRW), the Lévy flights (LF) or the Lévy walks (LW) are successfully used to describe these anomalous behaviors, they all have pros and cons. The CTRW is based on a concept of waiting times, or trappings, and can not be used in case of a continuous motion. Further, CTRW does not reproduce some statistical indices, such as the p-variation, of experimental data. The Lévy flights have diverging moments starting from the second one, and allow for infinite velocity.

The Lévy walks are devoid of these limitations, but instead imply a strong coupling between jump lengths and time.

In our work we suggest a novel model that features both anomalous (but non-diverging) time-scaling of the mean-squared displacement, and power-law alpha-stable-like tails of the coordinate probability density function. Our model is based on a non-ergodic Langevin equation and accounts for random properties of the medium and/or the walker itself. We present a rigorous comparison with the Lévy walk models. In particular, we show that, apart from the tails, the probability density of our model is very similar to that generated by the Lévy walk, while the comparison of several statistical indices display very different behaviors. We suggest that this analysis, applied to experimental data, could help in selecting the best modeling approach.

[l] P. Paradisi et. al., Rep. Math. Phys. **70**, 205 (2012).
[2] V. Zaburdaev et. al., Rev. Mod. Phys. **87**, 483 (2015).
[3] N. Gal, D. Weihs, Phys. Rev. E **81**, 020903-1 (2010).
[4] G. Ariel et al., Nature Comm. **6**, 8396 (2015).