Nonclassical chemical dynamics in living cells and complex material systems

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We will present novel chemical dynamics models and theories that enable an effective, quantitative description of biochemical reaction processes and their networks in living cells. Specifically, we will introduce the chemical fluctuation theorem (CFT), a general mathematical equation that links stochastic dynamics of mRNA and protein concentrations to gene expression mechanism and dynamics of elementary processes composing gene expression. We will demonstrate the successful applications of the CFT and its recent generalization in understanding of signal propagation and signal-induced gene expression dynamic in living cells. We will also discuss the mystery of stationary, monodisperse nuclei formation and multiphasic growth dynamics of small nanoparticles. These phenomena cannot be explained by the classical nucleation theory (CNT) or other currently available theories. We will present a new statistical mechanical theory of nucleation that sheds light on the origin of monodisperse nuclei formation and provides a unified, quantitative explanation of the complex growth dynamics of various metal nanoparticles.