Noise-induced multistability in chemical systems: Discrete versus continuum modeling

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Abstract: The dynamics of chemical and biochemical systems is noisy whenever the number of molecules of at least one chemical species is small. The analysis of such systems typically proceeds either via the chemical master equation (CME) or the chemical Fokker-Planck equation (CFPE). Although the latter is a continuous approximation of the discrete CME in the limit of large system size, recently it has been shown that for a particular system of reactions, the CFPE can capture the noise-induced multistability predicted by the CME. This phenomenon involves the switching from the unimodal probability distribution to the multimodal one as the system size decreases below a critical value. In this paper, the authors investigate whether the CFPE's stationary probability distribution has generally the same number of maxima (modes) as the CME's one. They show, by means of examples, that the CFPE does not always capture the noise-induced multimodality predicted by the CME. In particular, their findings clarify that there are two distinct types of noise-induced multimodality; one is those for which the CFPE can capture the inherent noise-induced multimodality and the other is those for which the CFPE fails to predict the phenomenon. The main difference between these two classes of systems is that in the former the switching between different states is described by the CFPE's diffusion term, whereas the multimodality studied in this paper cannot be so described.

References:

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