The dynamics of gene transcription with periodic synthesis rate

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Research Article

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Abstract

The periodic transcription output is ubiquitously observed in an isogenic cell population. To understand mechanisms of cyclic behavior in transcription, we extend the gene activation process in the two-state model by assuming the synthesis rate is periodic. We derive the analytical forms of the mean transcript level and the noise. The limits of them indicate the mean level and the noise display periodic behaviors. Our numerical examples strongly suggest that the transcription system with a periodic synthesis rate generates more noise than that with a constant rate, but maintains transcription homeostasis in each period. It also suggests that if the periodicity is not considered, the calculated noise may be greater than the correct value.

Full Text

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Figures

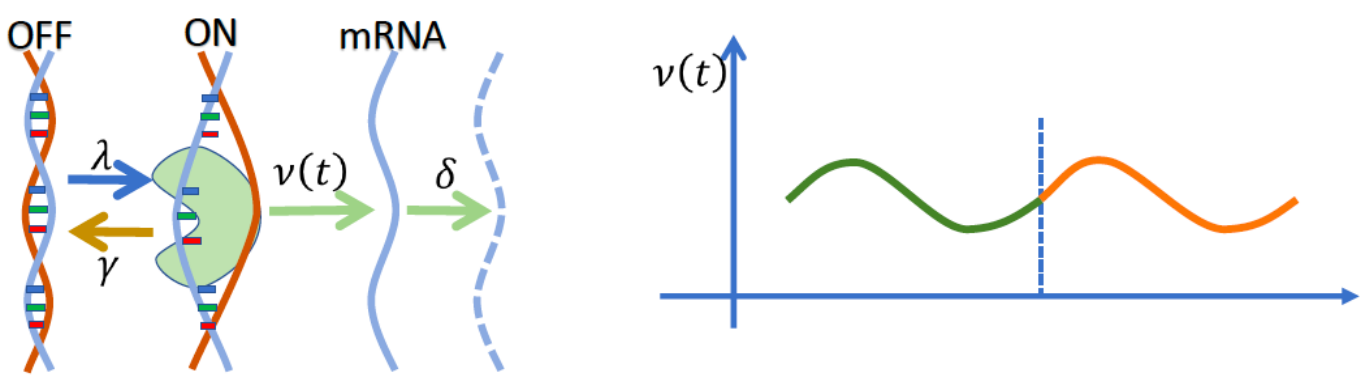

Figure 1

Stochastic gene transcription with a periodic synthesis rate. The promoter is activated by binding TFs at the enhancers forming a stable TF-DNA complex and binding RNA polymerase at the TATA box. RNA polymerases move along the template at the encoding region and synthesize RNA molecules with a periodic production rate v(t). RNA molecules are turned over with a constant rate δ.

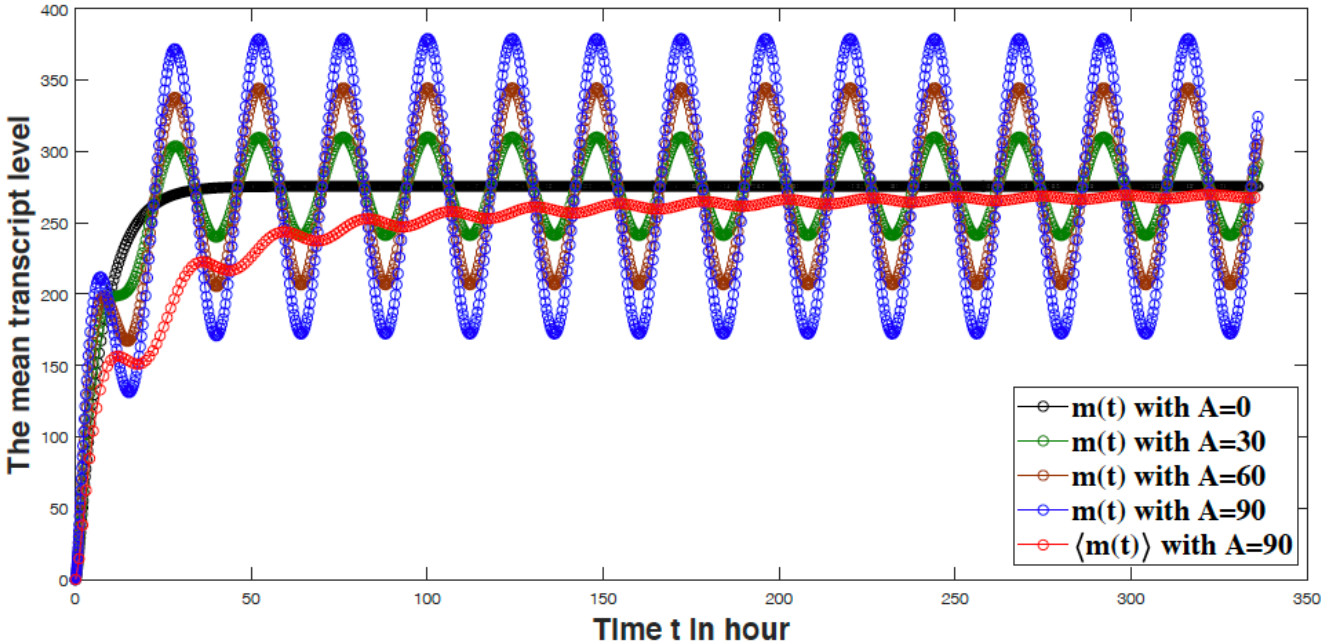

Figure 2

The mean transcript levels with different synthesis rates during fourteen days. When the synthesis rate $v(t) \equiv v0$ is a constant, the transcript level increases sharply and reaches an equilibrium state after one period. When v(t) is periodic with 24 hour the average transcript level tends to a periodic function, which is also periodic with 24 hour. And the amplitude of the mean level is proportional to the amplitude of v(t). For the case A = 90, the mean transcript level m(t), as shown by the blue curve, is almost periodic after one period, but its average value on time interval [0,t], as shown by the red curve, tends to a steady value.

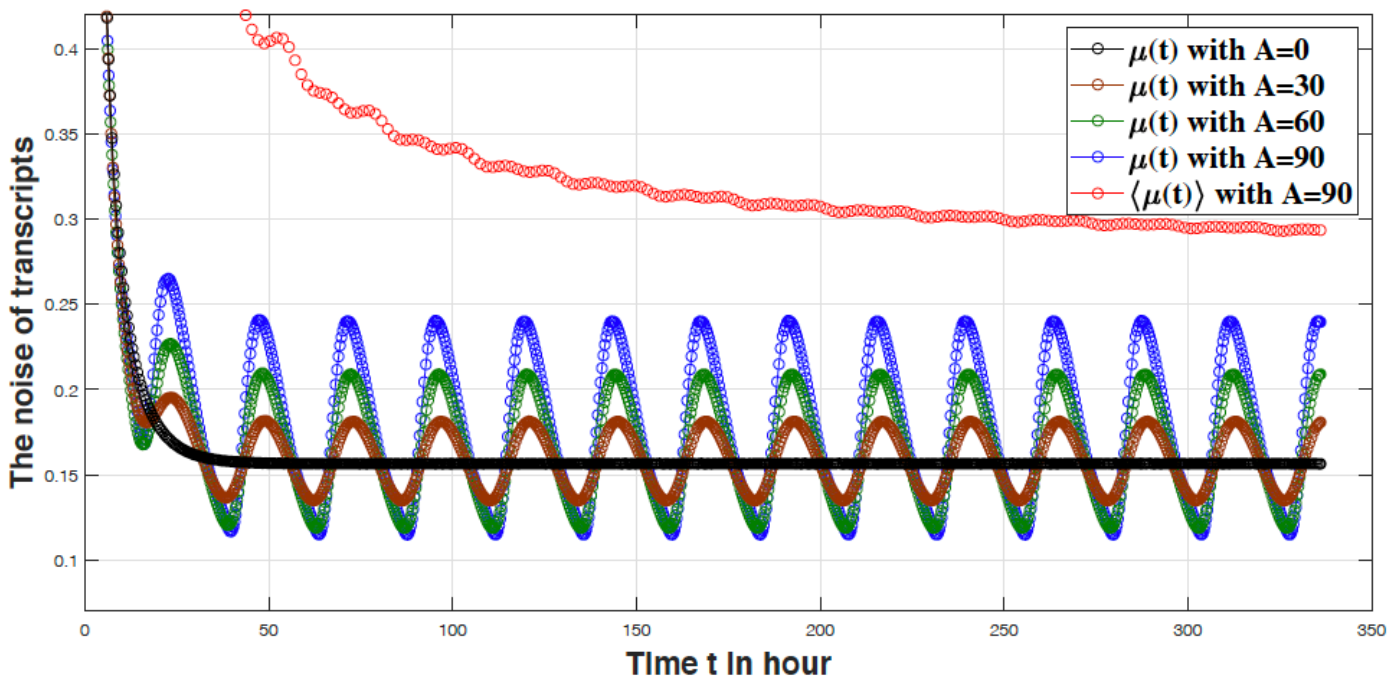

Figure 3

The noise of mRNA molecules. When v(t) is a constant, the noise η2(t) approaches its limit value (the black curve) after two periods. When v(t) is periodic, the noise η2(t) performs a periodic behavior after two periods. Same as the mean level m(t), the amplitude of the noise increases with the amplitude of v(t). When the time t goes to infinity, the average noise for transcriptional output over [0,t] approaches a steady value, which is greater than the limit of η2(t) with v(t) ≡ v0, as shown by the red curve.