Notes on transient states and short-term synaptic plasticity

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1 The dynamics

The equations for the two different models are:

Full depletion model	Tsodyks-Markram model (notes)
$\dot{u} = \frac{1+(U_{\max}-1)y-u}{T_u}$	$\dot{u} = \frac{1-u}{T_u} + \alpha(U-u)y$
$\dot{\varphi} = \frac{1-uy/U_{\max}-\varphi}{T_\varphi}$	$\dot{\varphi} = \frac{1-\varphi}{T_\varphi} - \alpha\varphi u y$
Therefore	
$u \in [1, U_{\max}]$	$u \in [1, u^*] = \left[1, \frac{1+\alpha T_u U_{\max}}{1+\alpha T_u}\right]$
$\varphi \in [0, 1]$	$\varphi \in [\varphi^*, 1] = \left[\frac{1}{1+\alpha u^* T_\varphi}, 1\right]$

In the full depletion model I have used $U_{\max} = 4$, $\tau_u = 30\,\text{ms}$ and $\tau_\varphi = 60\,\text{ms}$, that create a continuously active network.

For the Tsodyks-Markram model, Bulcsù has used $\tau_u = 21\,\text{ms}$, $\tau_\varphi = 706\,\text{ms}$ that are taken from Gupta et. al 2000, $U = 4$ and $\alpha = 1/100\,\text{ms}^{-1}$. With these parameters, the dynamics of the clique network is dominated by fixed points, see Fig. 1 on the left.

Comparing the two models, as in Fig 2, one can see that with these parameters the depression of inhibitory synapses dominates because of the small range of $u \in [1, 1.58]$, and what would be the winning clique cannot dominate over the others.

Defining a fixpoint as a point in which $\dot{x}_i < 10^{-10}\,\forall i$, we can vary U and measure when a fixpoint is reached, see Fig. 1 on the right. There is a steep increase of around $U \approx 15$, up to the total simulation time of 300 ms. A new network is generated at every run.

Unfortunately a given value of U_m does not ensure autonomous activity for networks with different number of cliques n_c, see Fig. 3.

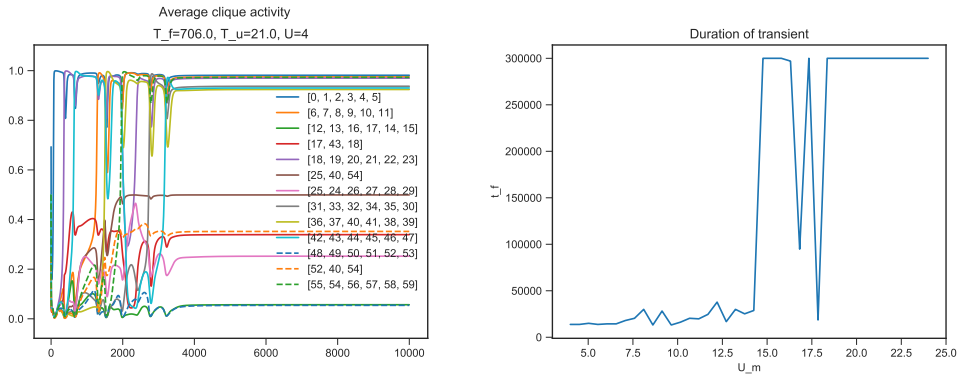

Figure 1: Left: The dynamics is characterized by fixpoints with $U = 4$, $\tau_u = 21\,\text{ms}$, $\tau_\varphi = 706\,\text{ms}$. Right: Duration of transient until a fixpoint is reached. As U increases, an autonomous activity eventually takes over.

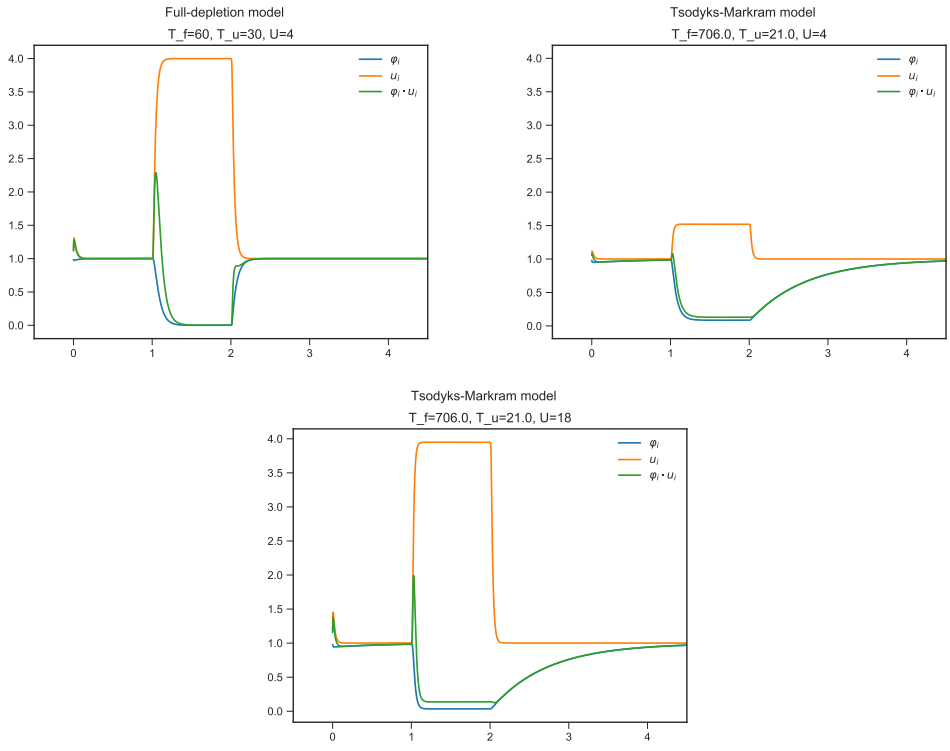

Figure 2: Top left: full depletion model used up to now. Top right: Tsodyks-Markram model from Gupta. Bottom: Tsodyks-Markram model with $u_m = 18$.

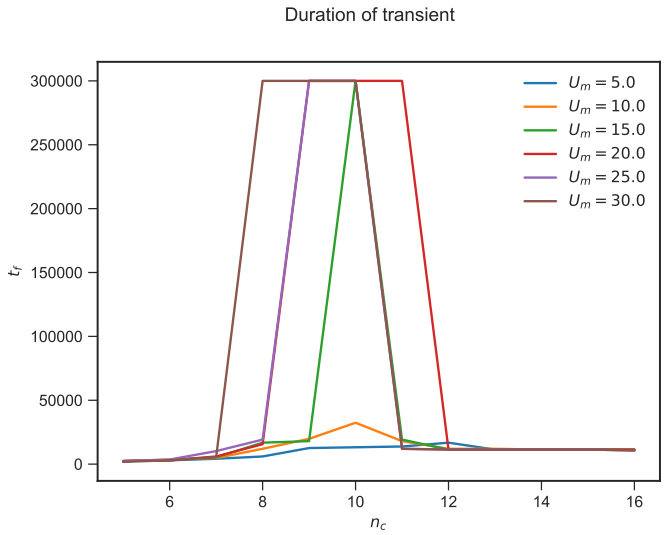
Duration of transient
300000
250000
200000
150000
100000
50000
0
t_f
6
8
10
12
14
16
n_c
$U_m = 5.0$
$U_m = 10.0$
$U_m = 15.0$
$U_m = 20.0$
$U_m = 25.0$
$U_m = 30.0$

Figure 3: