Calcium Activity in Astrocytes

Evan Cresswell
Intro

• View of Astrocytes has changed
• metabolic and structural support to modulating maintaining neural activity
• Wave of research has ebbed and flowed our perception
• These advances the product of enhanced imaging technique!
Goals

• What determines how local becomes global
• How can distinct astrocytic processes have independent activity
• What direction does information flow
• Do global and local affect the synapse differently
• What’s up with the ER?
Model

- Like previous models, oscillations are initiated by interaction between the ER and the cytosol
- Both the ER and the cytosol have been compartmentalized
  - Used a Postnov model and modeled the soma and its branches individually
- Neurons – FitzHugh-Nagumo
- Synapse – sigmoid function
- Cytosol and ER – Keener and Sneyd calcium model with diffusion
- Secondary Messenger – sigmoid function triggered by synaptic Activity
- Glial Messenger – sigmoid function triggered by calcium activity

<table>
<thead>
<tr>
<th>Section</th>
<th>Equations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre – Synaptic Neuron</td>
<td>$\frac{dx_{\text{pre}}}{dt} = v_{\text{pre}} - \frac{v_{\text{pre}}^3}{3} - w_{\text{pre}}$</td>
<td>FitzHugh – Nagumo Mod</td>
</tr>
<tr>
<td>Synapse</td>
<td>$\tau_w \frac{dw_{\text{pre}}}{dt} = (1 + \tanh(v_{\text{pre}} - \theta_w))(1 - w_{\text{pre}}) - \frac{w_{\text{pre}}}{\tau_w}$</td>
<td>activation variable</td>
</tr>
<tr>
<td>Post – Synaptic Neuron</td>
<td>$\frac{dx_{\text{post}}}{dt} = v_{\text{post}} - \frac{v_{\text{post}}^3}{3} - w_{\text{post}}$</td>
<td>FitzHugh – Nagumo Mod</td>
</tr>
<tr>
<td>Astrocytic Ca$^{2+}$</td>
<td>$\tau_{\text{Ca}^{2+}} \frac{dC_{\text{Ca}^{2+}}}{dt} = r + \alpha_{\text{Ca}^{2+}} + \beta_{\text{Ca}^{2+}} \cdot C_{\text{Ca}^{2+}} - f(C_{\text{Ca}^{2+}}, C_{\text{Ca}^{2+}}) + d(C_{\text{Ca}^{2+}} - C_{\text{Ca}^{2+}})$</td>
<td>$f$ from CalciumPathway</td>
</tr>
<tr>
<td>Secondary Messenger</td>
<td>$\tau_{\text{sec}} \frac{dS_{\text{sec}}}{dt} = \theta_{\text{sec}} - \frac{S_{\text{sec}}}{\tau_{\text{sec}}}$</td>
<td>activation variable</td>
</tr>
<tr>
<td>Glutamate Messenger</td>
<td>$\tau_{\text{Glu}} \frac{dG_{\text{Glu}}}{dt} = \theta_{\text{Glu}} - \frac{G_{\text{Glu}}}{\tau_{\text{Glu}}}$</td>
<td>activation variable</td>
</tr>
</tbody>
</table>
Periodic Behavior
Basic Calcium Dynamics

• First step to understand

• Able to reproduce similar dynamics to Postnov’s paper
  – Changed alpha and beta
Basic Calcium Dynamics: alpha

Alpha=.01, .05, .1

Higher firing probability.
Basic Calcium Dynamics: beta
Basic Calcium Dynamics: Influence?

- Which direction is information going in?
Batch Results

• Very exciting work!
  – Can tell us a lot of things about the behavior of our model
• Future directions?
Batch Results: Diffusion
Batch Results: Bifurcation

- Shows two par bifurcation diagram
- Great visualization
- Folds show emergence of harmonics!
  - What does this mean? artifact or jewel