Calcium Activity in Astrocytes

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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!

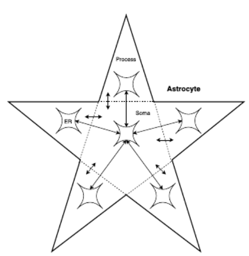
Goals

- 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?

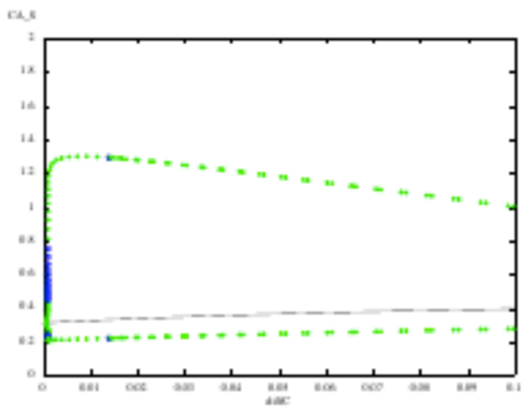
Model

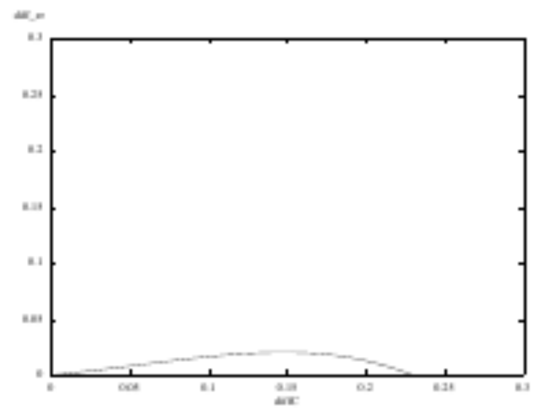
- Like previous models, oscillations are initiated by interaction between the ER and the cytosol
- Both the ER and the cytosol have been compartmentalized
    - Used a Postnov model and modeled the soma and its branches individually
- Neurons – FitzHugh-Nagumo
- Synapse – sigmoid function
- Cytosol and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

Section	Equations	Description
Pre – Synaptic Neuron	$\epsilon_1 \frac{dv_{pre_i}}{dt} = v_{pre_i} - \frac{v_{pre_i}^3}{3} - w_{pre_i}$ $\frac{w_{pre_i}}{dt} = v_{pre_i} + I_1 - I_{app}$	*FitzHugh – Nagumo Mode*
Synapse	$\tau_s \frac{dz_i}{dt} = (1 + \tanh(s_s(v_{pre_i} - h_s)))(1 - z_i) - \frac{z_i}{d_s}$	*activation variable*
Post – Synaptic Neuron	$\epsilon_2 \frac{dv_{post_i}}{dt} = v_{post_i} - \frac{v_{post_i}^3}{3} - w_{post_i}$ $\frac{dw_{post_i}}{dt} = v_{post_i} + I_2 - I_{syn_i} - I_{glion_i}$	*FitzHugh – Nagumo Mode*
Astrocytic Ca^{2+}	$\tau_c \frac{dCa_{p_i}}{dt} = r + \alpha w_{post_i} + \beta Sm_i - c_4 * f(Ca_{P_i}, Ca_{er_i}) + d_c(Ca_s - Ca_{p_i}) - Ca_{p_i}$ $\epsilon_c \tau_c \frac{dCa_{er_i}}{dt} = f(Ca_{p_i}, Ca_{er_i}) + d_{er}(Ca_{er_s} - Ca_{er_i})$ $\tau_c \frac{dCa_s}{dt} = -Ca_s - c_4 * f(Ca_s, Ca_e) + r + \sum_{i=1}^{n} d_c(Ca_{p_i} - Ca_s)$ $\epsilon_c \tau_c \frac{dCa_{er_s}}{dt} = f(Ca_s, Ca_{er_s}) + \sum_{i=1}^{n} d_{er}(Ca_{er_i} - Ca_{er_s})$	*fast/slow CalciumPathwa*
Secondary Messenger	$\tau_{S_m} \frac{dS_{m_i}}{dt} = (1 + \tanh(s_{Sm}(z - h_{Sm})))(1 - S_{m_i}) - \frac{S_{m_i}}{d_{S_m}}$	*activation variable*
Glutamate Messenger	$\tau_{Gm} \frac{dG_{m_i}}{dt} = (1 + \tanh(s_{G_m}(Ca_{p_i} - h_{G_m})))(1 - G_{m_i}) - \frac{G_{m_i}}{d_{G_m}}$	*activation variable*



Periodic Behavior

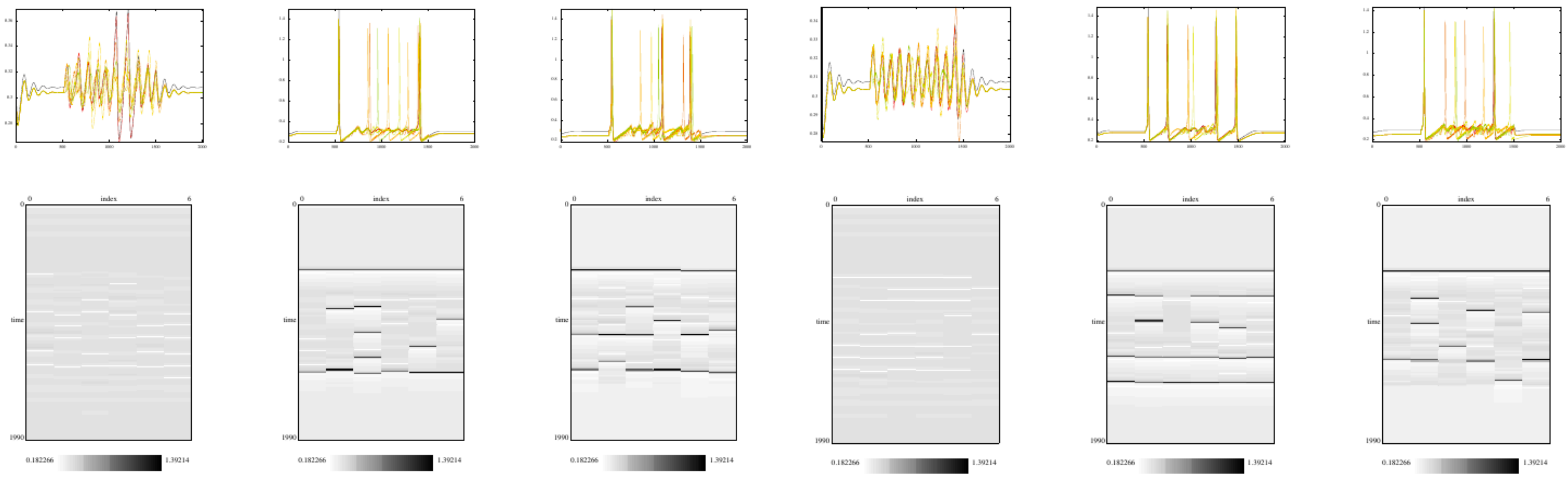




Basic Calcium Dynamics

- First step to understand
- Able to reproduce similar dynamics to Postnov’s paper
  - Changed alpha and beta

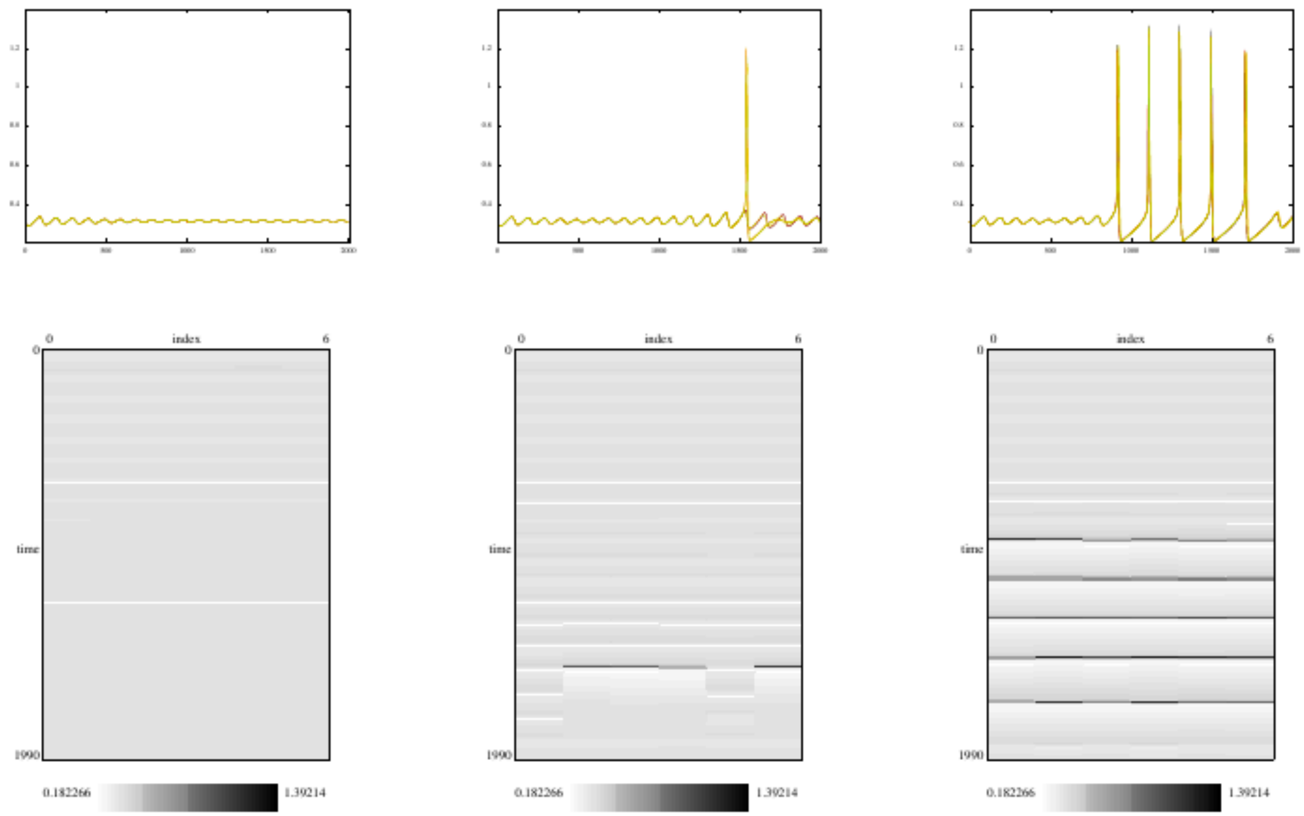
Basic Calcium Dynamics: alpha



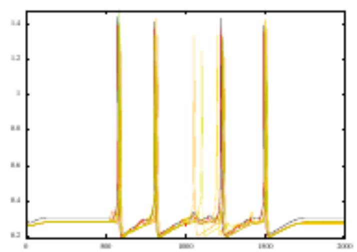
Alpha=.01, .05, .1

Higher firing
probability.

Basic Calcium Dynamics: beta



Basic Calcium Dynamics: Influence?

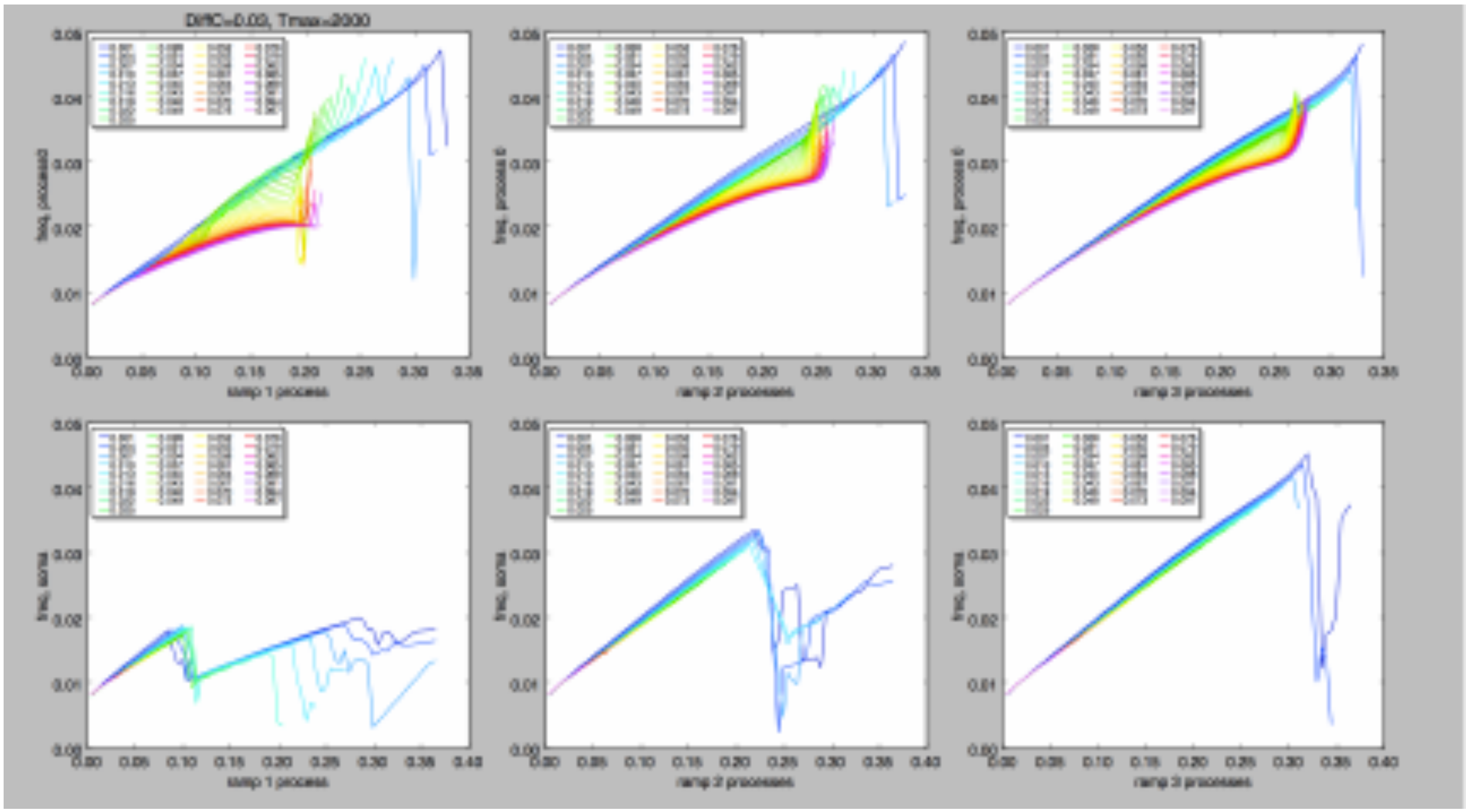


- Which direction is information going in?

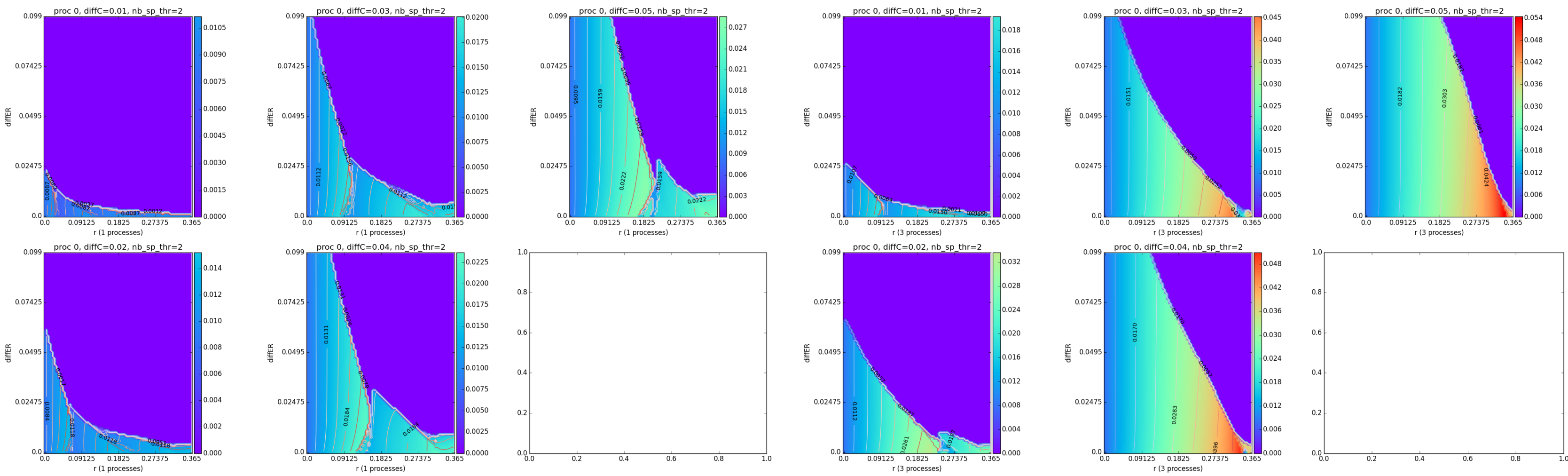
Batch Results

- 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