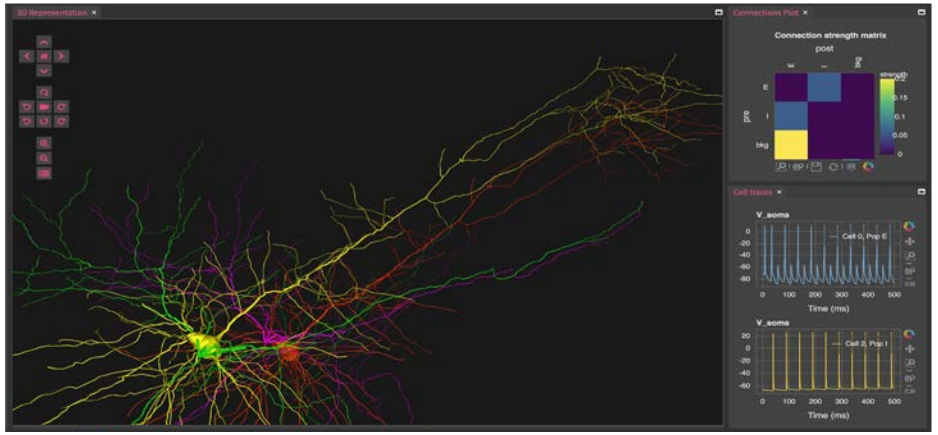
Breakout Session 2: Track B

Dissemination of a Tool for Data-driven Multiscale Modeling of Brain Circuits (U24EB028998)

Dr. Salvador Dura-Bernal
Assistant Professor, SUNY Downstate

Dissemination of a tool for data-driven multiscale modeling of brain circuits (U24EB028998)

Admin Supp: "Exploring cloud GPUs to accelerate multiscale simulations of brain circuits using NetPyNE and CoreNEURON"

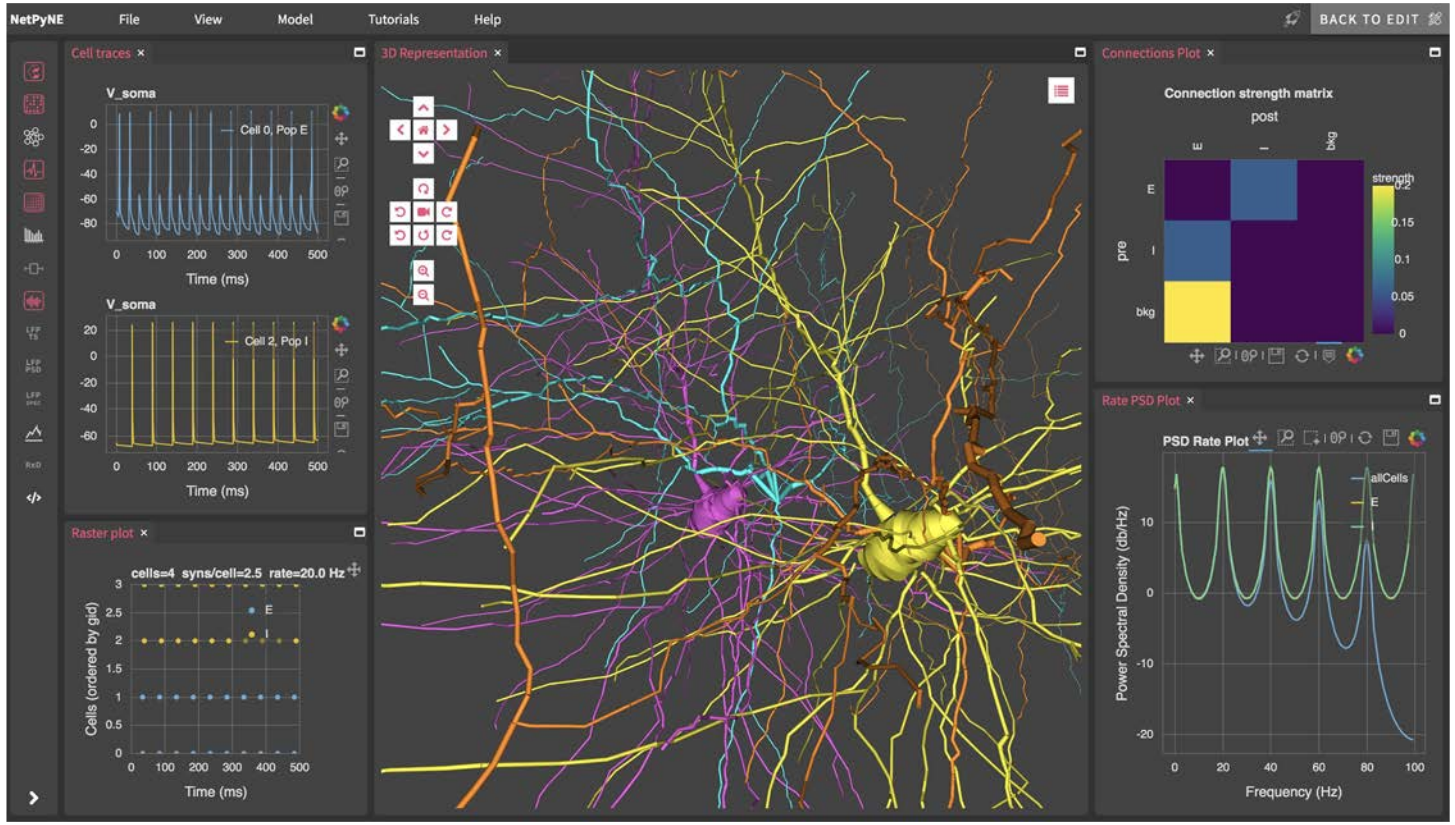


PI: Salvador Dura-Bernal, PhD
Assistant Professor, State University of New York (SUNY) Downstate
Research Scientist IV, Nathan Kline Institute for Psychiatric Research

Lab web: dura-bernal.org

NetPyNE

A python package to facilitate the development, parallel simulation, optimization and analysis of biological neuronal networks using the NEURON simulator.



Funded by:

National Institutes of Health

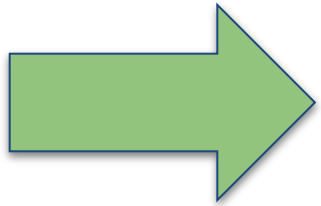
Dura-Bernal et al, 2019, eLife

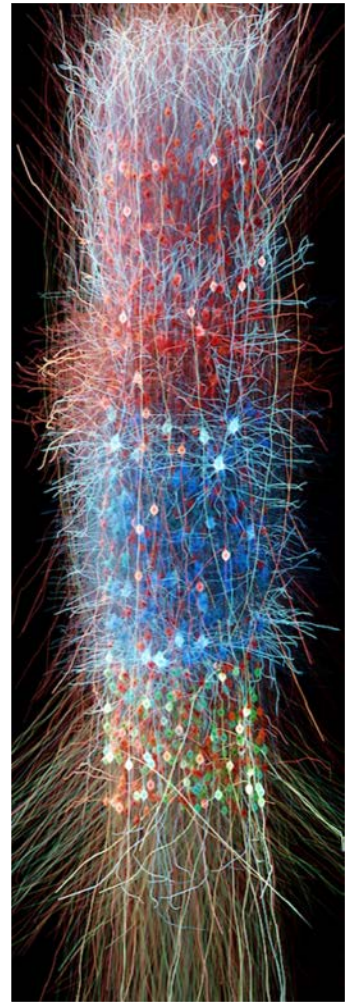
High level specifications

A **standardized, declarative, human-readable** Python format to define the model

```
popParams['EXC_L2'] = {
'cellType':   'PYR',
'cellModel':  'simple',
'yRange':     [100, 400],
'numCells':   50}
```

```
connParams['L2->E2'] = {
 'preConds':    {'y': [100, 400]},
 'postConds':   {'pop': 'EXC_L2'},
 'probability': '1*exp(-dist_3D/200)',
 'weight':       0.4,
 'delay':        5,
 'synMech':      'AMPA'}
```

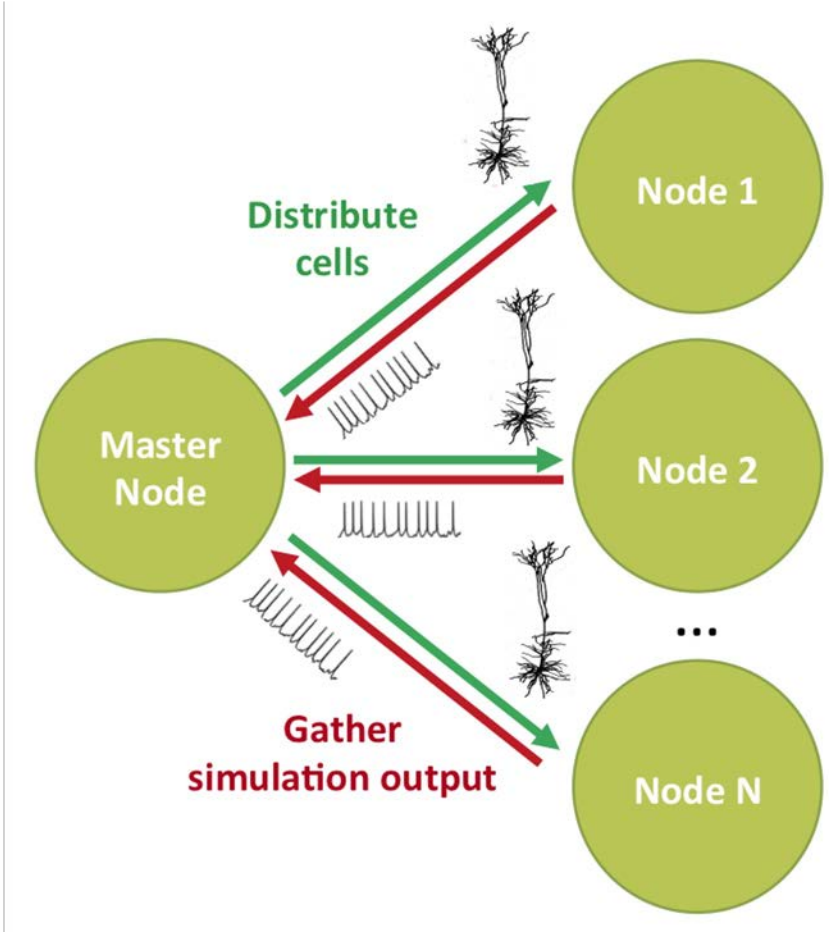




Dura-Bernal et al, 2019, eLife

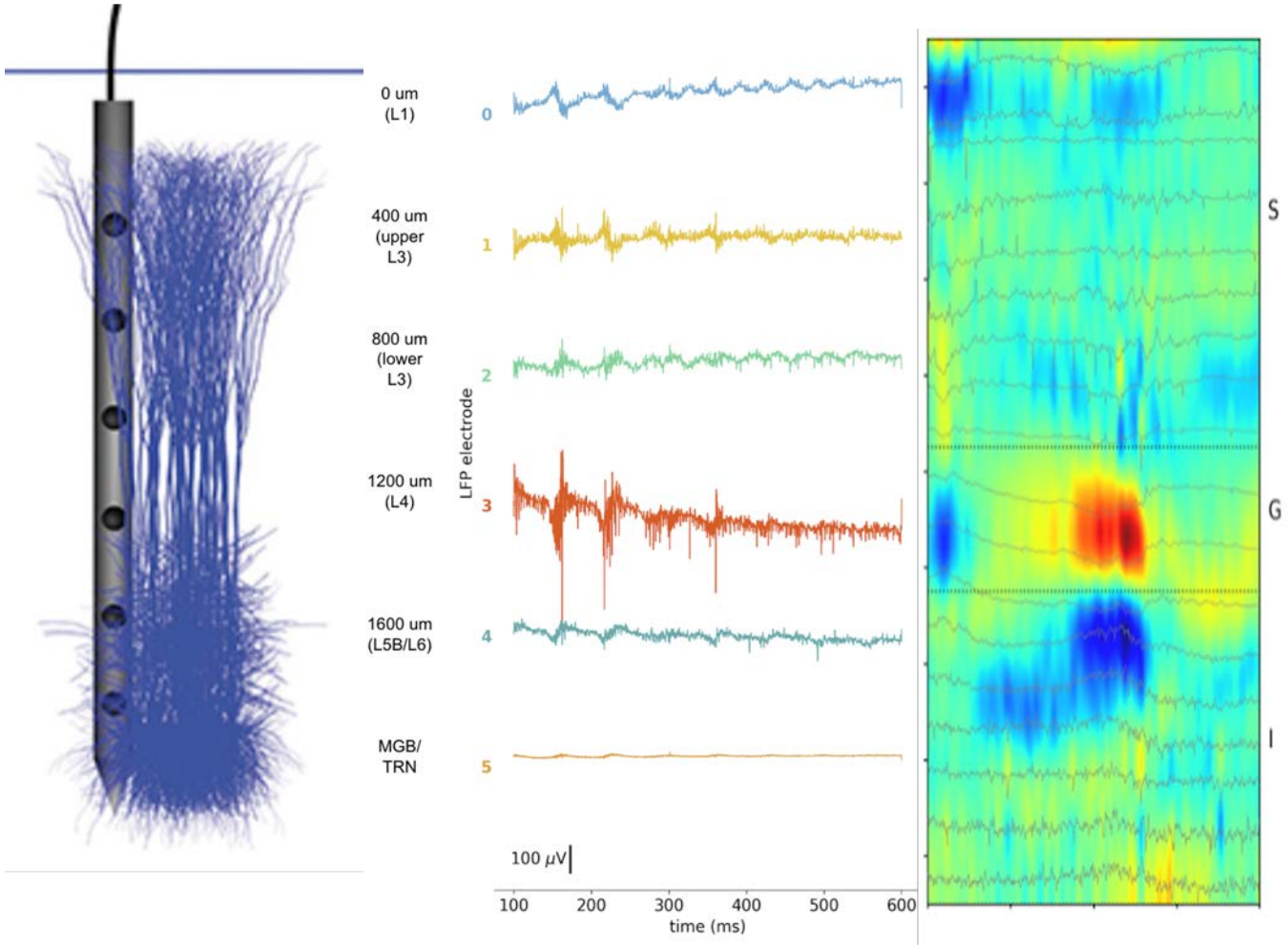
Parallel Simulation

- Set up for MPI **parallel simulation** across multiple nodes (via NEURON simulator).
- Takes care of balanced **distribution** of cells and **gathering** of simulation output from nodes.

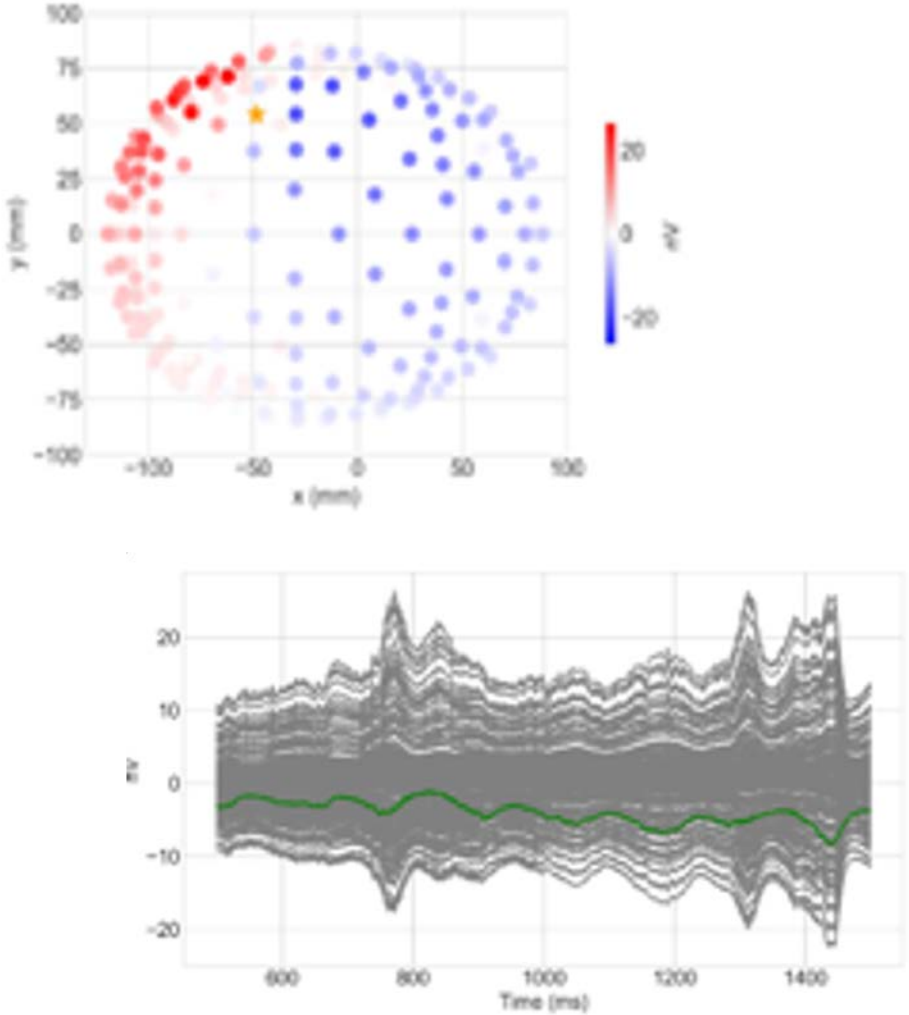


Multiscale measures

LFP / CSD

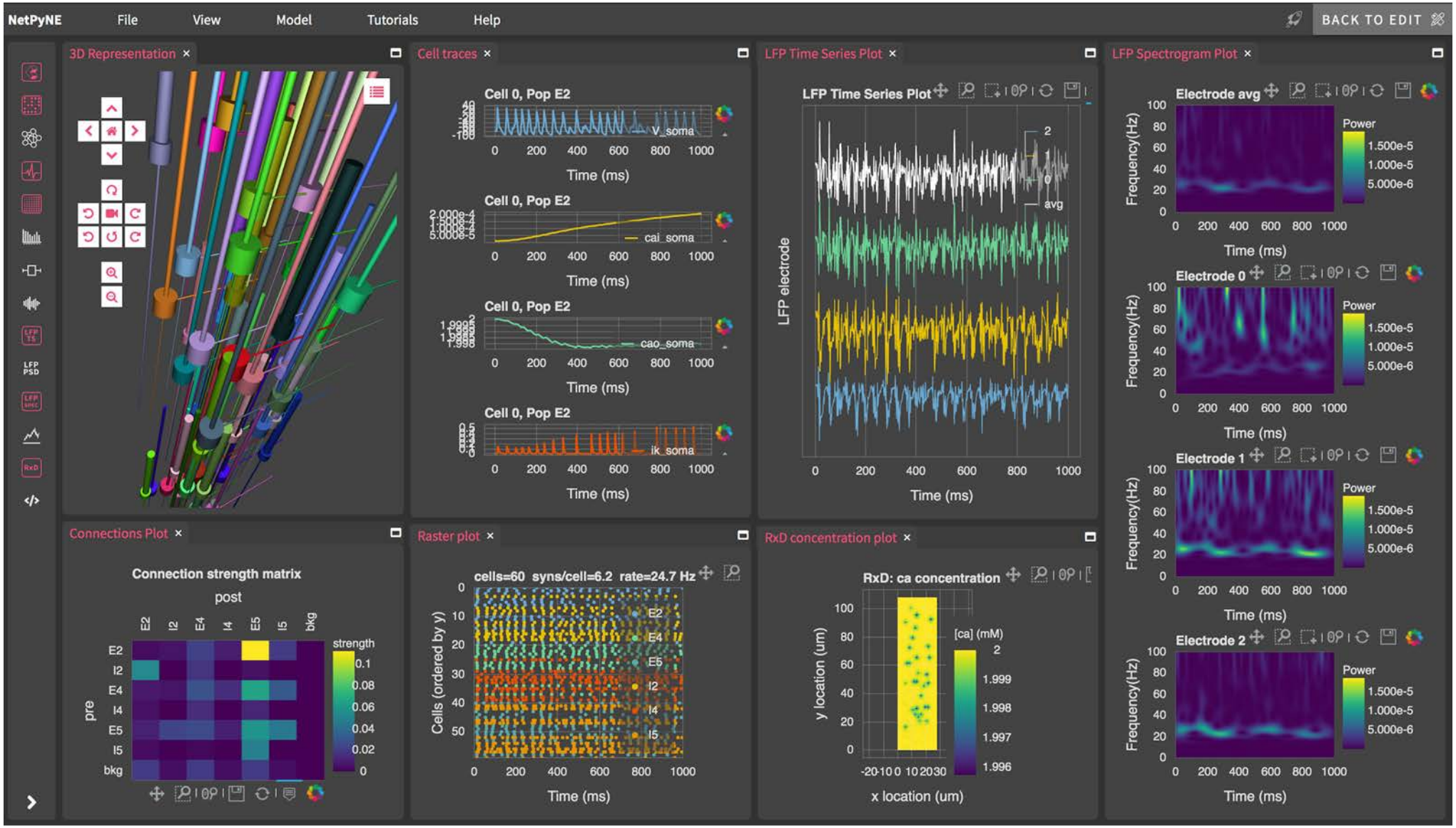


EEG / Current Dipoles



Dura-Bernal et al, 2019, eLife

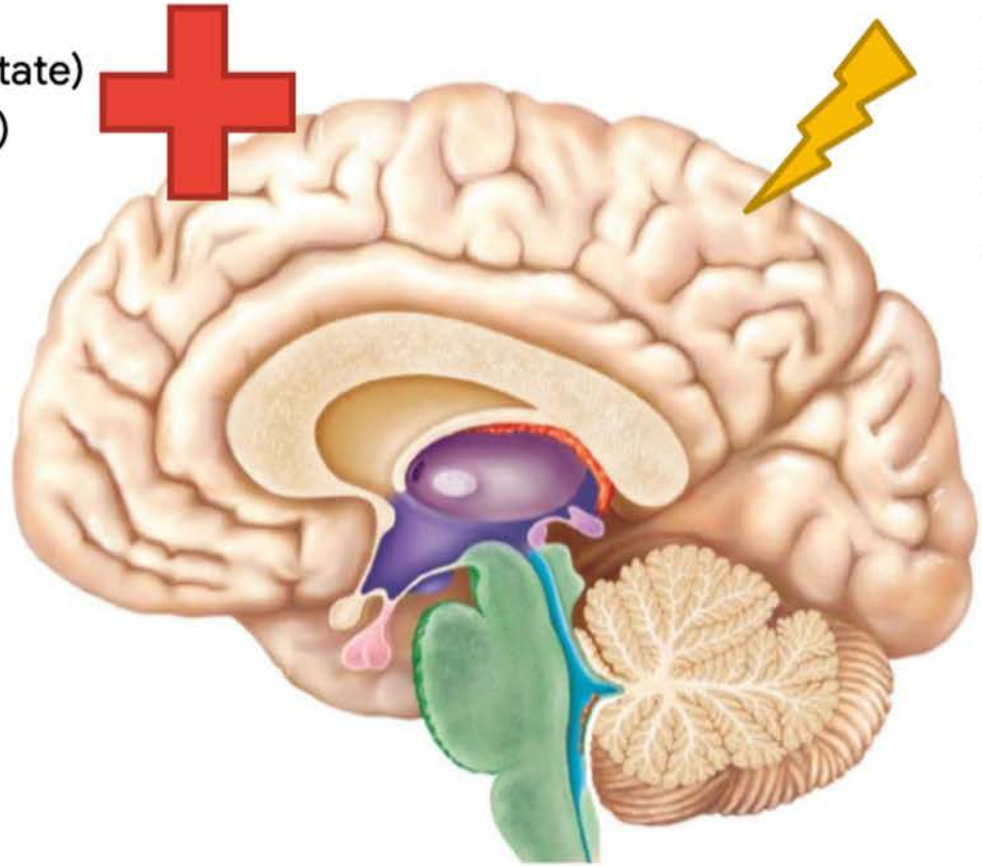
GUI for Development, Simulation, Analysis



Growing NetPyNE community: >50 Labs, >90 models

- Schizophrenia (TU Berlin, Brown)
- Ischemic stroke (Yale, Downstate)
- Epilepsy (Cincinatti, Brown, Downstate)
- Chronic Pain (Okinawa, Downstate)
- Depression (Brown)
- Parkinson's (Edinburgh)

- TMS / tDCS / tACS (Duke, Toronto)
- Optogenetics (Sydney)
- Electrical stimulation (Downstate)
- Ketamine (Brown)
- EEG/MEG (Puerto Rico, Brown, Rice)
- fMRI (Linkopig)



- PFC (Sao Paulo)
- Thalamus (UCL, Missouri)
- Olfactory Bulb (Palermo)
- Striatum (Dublin)
- Amygdala (Princeton)
- Hippocampus (Sao Paulo)

- M1 and S1 (Downstate)
- A1 (NKI)
- V1 (Queensland, Sao Paulo)
- Claustrum (Singapore)
- Cerebellum (Sao Paulo)
- Spinal Cord (Northeastern)

- Cardiac circuits (Jefferson, Downstate, Pavia)

- Enteric / gastrointestinal circuits (Melbourne)

NetPyNE used in >30 publications

Schizophrenia

ARTICLE OPEN

Check for updates

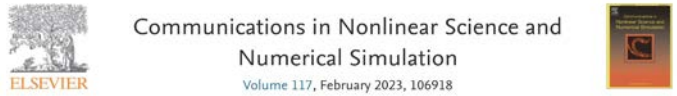
The effect of alterations of schizophrenia-associated genes on gamma band oscillations

Christoph Metzner[1,2✉], Tuomo Mäki-Marttunen[3], Gili Karni[1,4], Hana McMahon-Cole[1,4] and Volker Steuber[2]

Neurobiology of Disease
Volume 179, April 2023, 106059

Biophysical characterization and modelling of *SCN1A* gain-of-function predicts interneuron hyperexcitability and a predisposition to network instability through homeostatic plasticity

Géza Berecki [a 1], Alexander Bryson [a b 1], Tilman Polster [c], Steven Petrou [a d e]



Communications in Nonlinear Science and Numerical Simulation
Volume 117, February 2023, 106918

Research paper

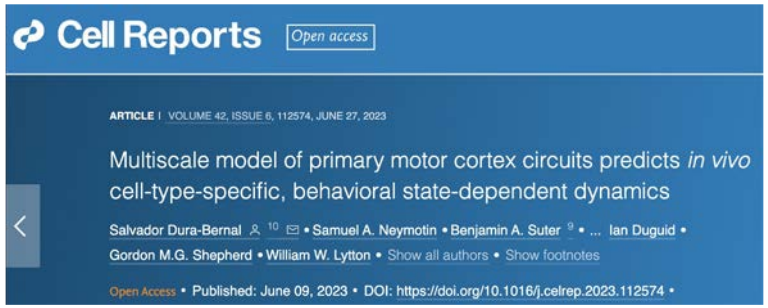
Optogenetic stimulation of primary motor cortex regulates beta oscillations in the basal ganglia: A Computational study

Ying Yu [a], Yubo Fan [b], Songan Hou [c], Qingyun Wang [c d]

1986 IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING, VOL. 31, 2023

A Hippocampal-Entorhinal Cortex Neuronal Network for Dynamical Mechanisms of Epileptic Seizure

Ying Yu, Fang Han, and Qingyun Wang



Cell Reports Open access

ARTICLE | VOLUME 42, ISSUE 6, 112574, JUNE 27, 2023

Multiscale model of primary motor cortex circuits predicts *in vivo* cell-type-specific, behavioral state-dependent dynamics

Salvador Dura-Bernal • Samuel A. Neymotin • Benjamin A. Suter • ... Ian Duguid • Gordon M.G. Shepherd • William W. Lytton • Show all authors • Show footnotes

Open Access • Published: June 09, 2023 • DOI: https://doi.org/10.1016/j.celrep.2023.112574 •

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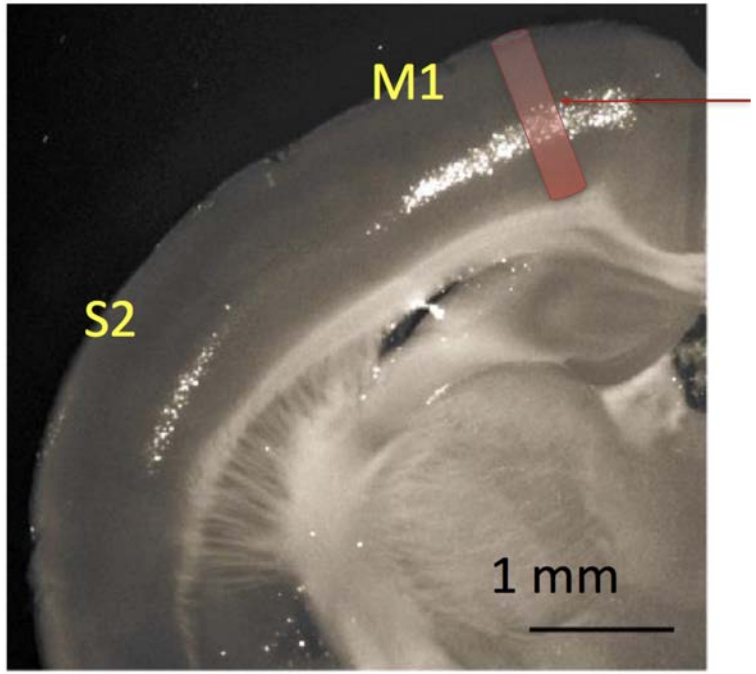
Active Grants using NetPyNE (US-based)

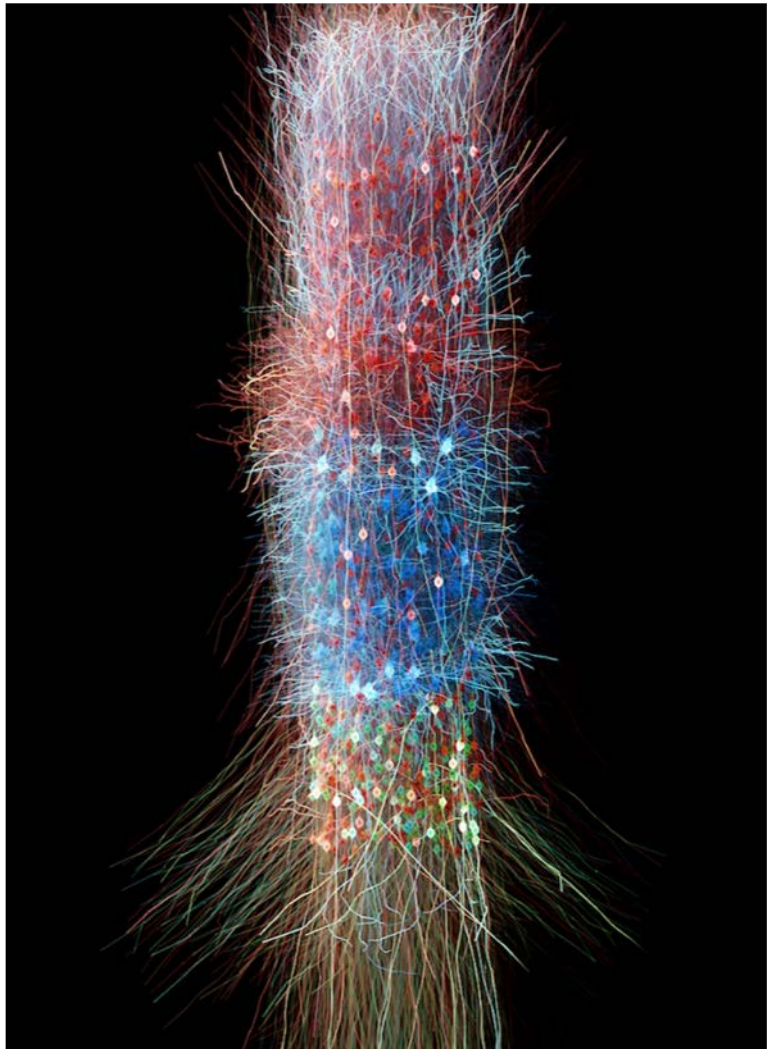
- **2023-2028; $18M;** NIH Conte Center P50: "Neurobiology and Cognitive Role of Slow Brain Network Fluctuations”
- **2023-2028; $4.5M;** NIH R01: "Neural Recording and Simulation Tools to Address the Mesoscale Gap"
- **2023-2028; $3.5M**; NIH R01: "Dynamic circuit motifs underlying multimodal interactions in primate auditory cortex"
- **2023-2028; $300k**; NYS DOH : "Restoring motor function after spinal cord injury using multiscale modeling to decode neural latent dynamics from motor cortex EEG"
- **2023-2027; $3.7M**; NIH U24: "Advancing Bio-Realistic Modeling via the Brain Modeling ToolKit and SONATA Data Format"
- **2023-2026; $300k**; The Hartwell Foundation: “Utilizing neuronal simulations to tailor therapies for children suffering from channelopathy related neurodevelopmental disorders”
- **2022-2026; $2M;** NIH R01: "Extension of NEURON simulator for simulation of reaction-diffusion in neurons"
- **2022-2025; $3.5M;** NIH R01: "Secondary analysis of resting state MEG data using the Human Neocortical Neurosolver software tool for cellular and circuit-level interpretation"
- **2021-2023; $330k;** NIH R21: "Combined EEG and in silico modeling to investigate the mechanisms of ketamine's sustained antidepressant effect in patients"
- **2019-2023; $3.4M**; NIH R01: "Cortical and thalamic mechanisms of selective auditory attention"
- **2019-2023; $1.5M**; NIH U24: "Dissemination of a tool for multiscale modeling of brain circuits"
- **TOTAL: >$40M**; (+6 grants under review > $20M)

Detailed model of motor cortex (M1) circuits

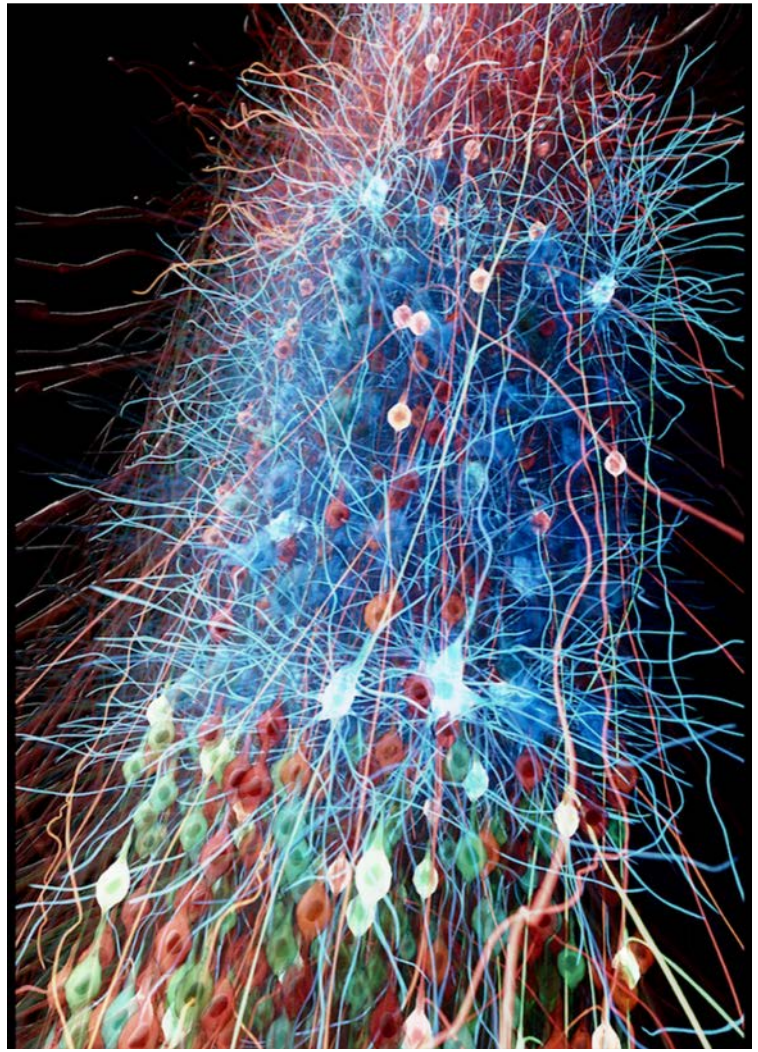
300 um diameter column



10,000 neurons

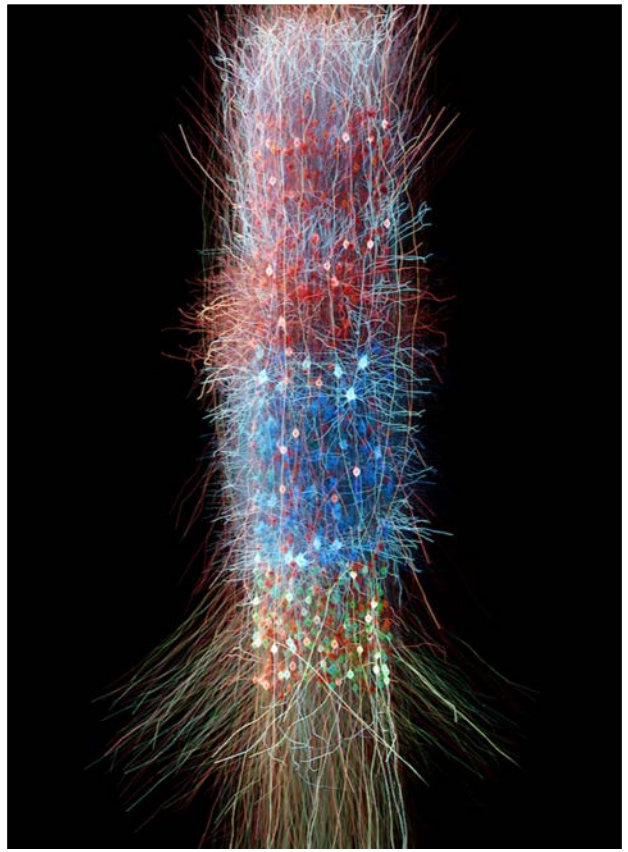


30 million connections



A simulation requires a lot of computing power

1 second simulation



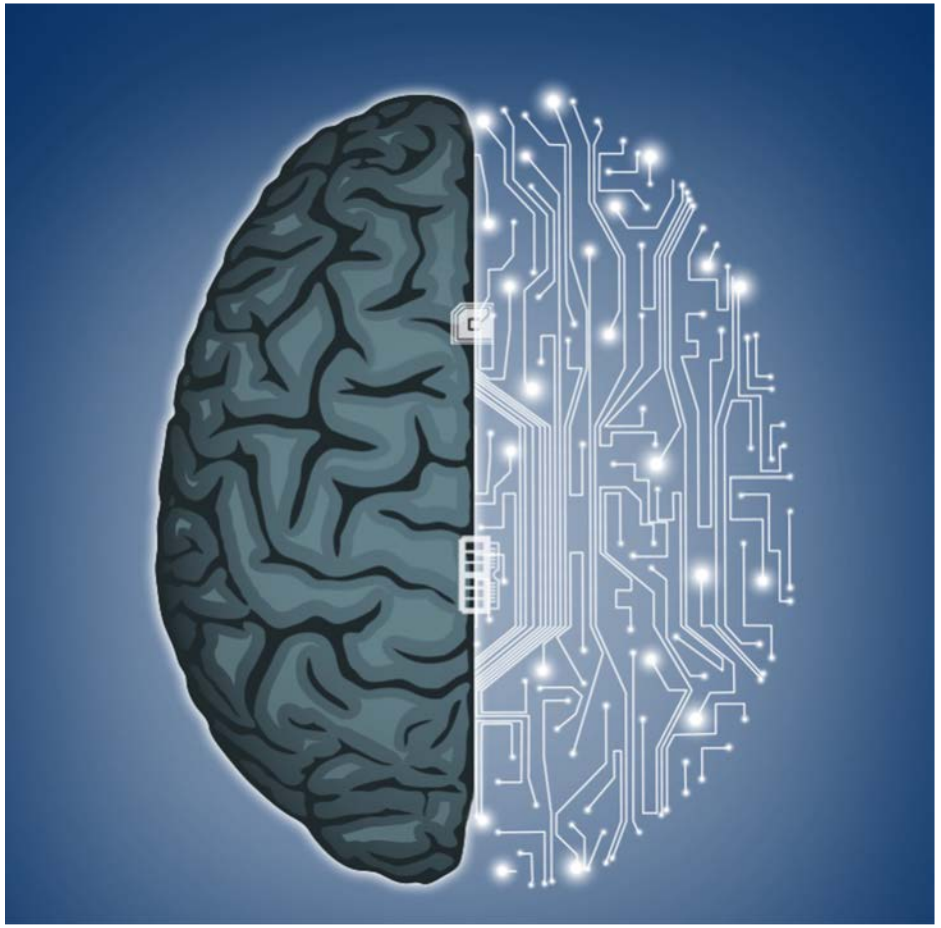
100 cores

3 hours

Need to run 1000s of simulations

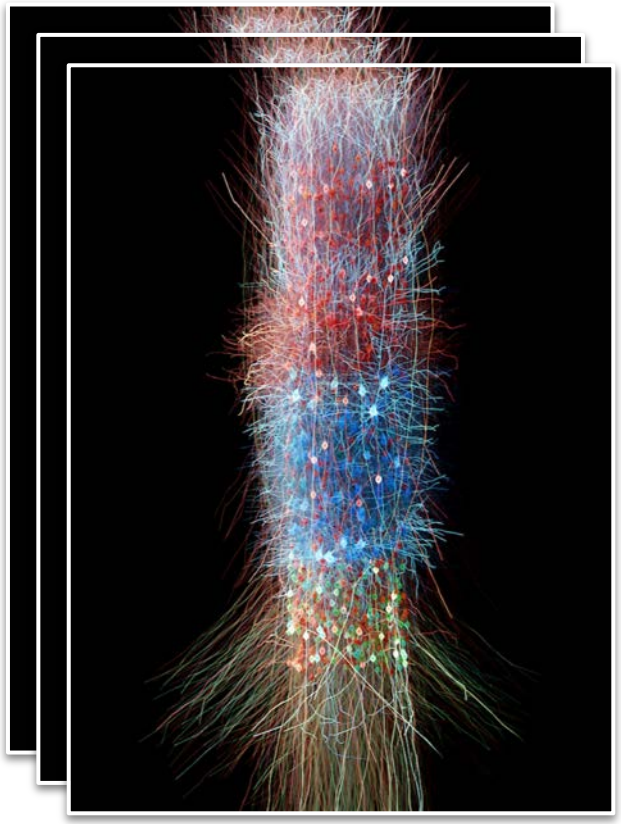
1) Find model parameters that reproduce real brain activity

1) Experiment with simulated brain



1000s of simulations require massive power

1000 x 1 second simulations

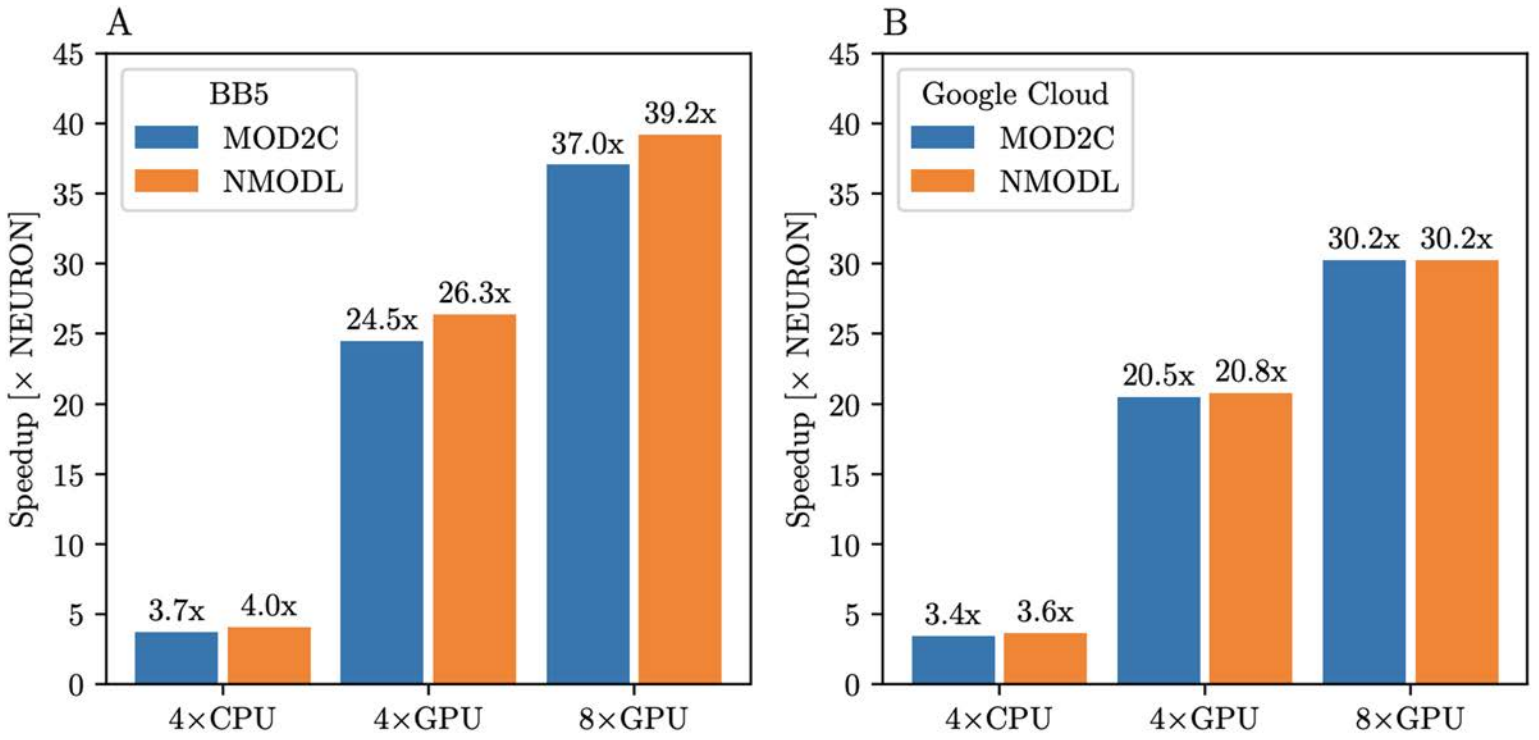


100,000 cores

3 hours

"Exploring cloud GPUs to accelerate multiscale simulations of brain circuits using NetPyNE and CoreNEURON"

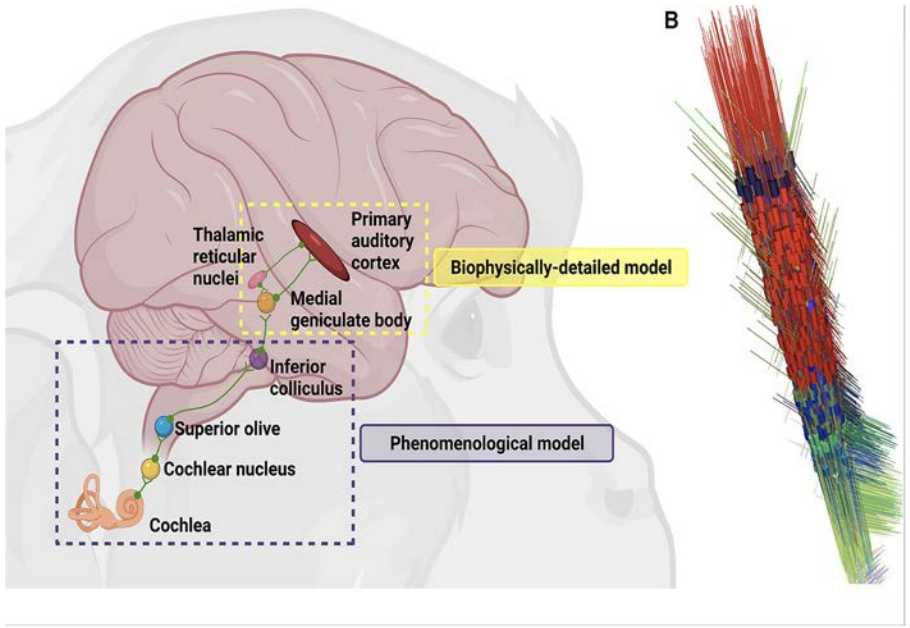
Up to 40x speedup using GPUs



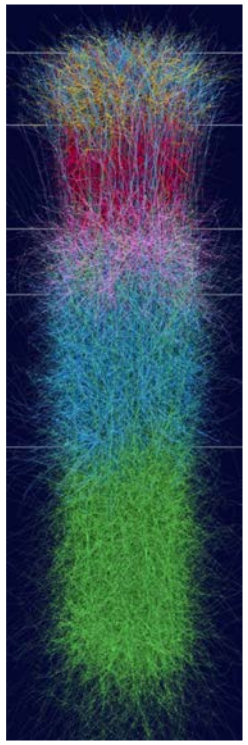
"Exploring cloud GPUs to accelerate multiscale simulations of brain circuits using NetPyNE and CoreNEURON"

Aim 1: Evaluate cloud GPUs to simulate large-scale brain circuit models

Auditory thalamocortical model (14k neurons)



Somatosensory cortical model (37k neurons)



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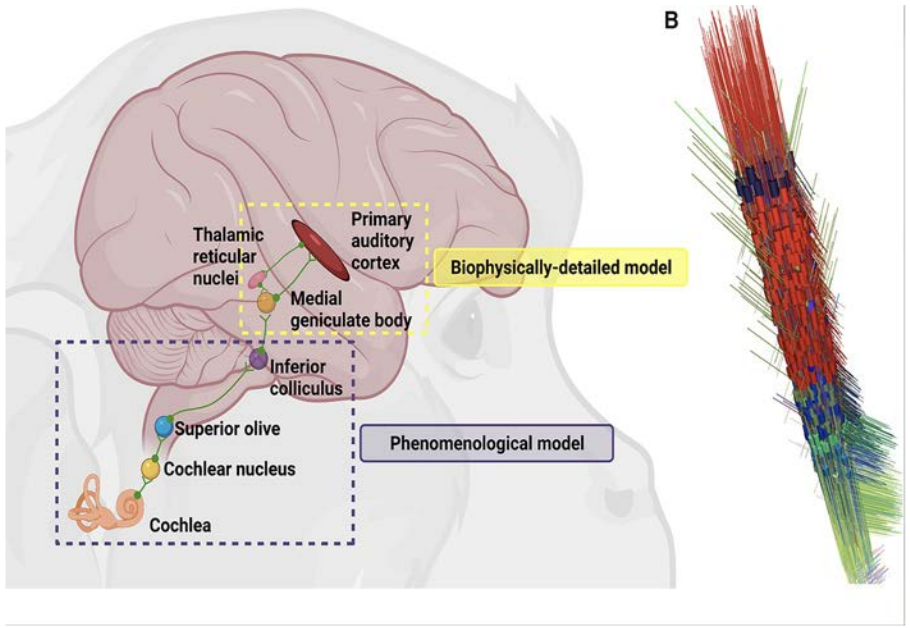

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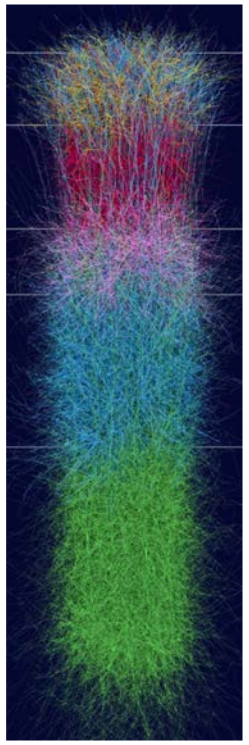
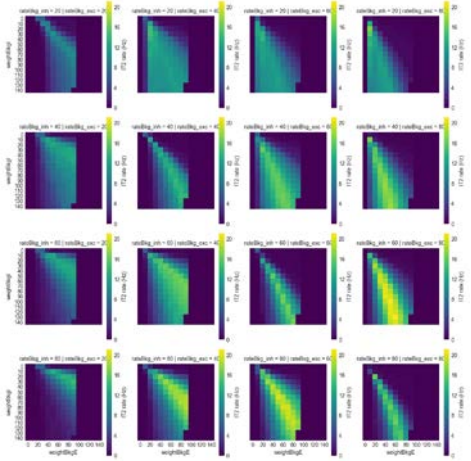


Cloud GPUs

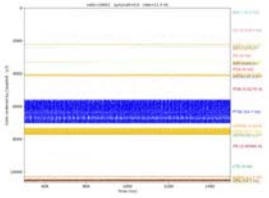
"Exploring cloud GPUs to accelerate multiscale simulations of brain circuits using NetPyNE and CoreNEURON"

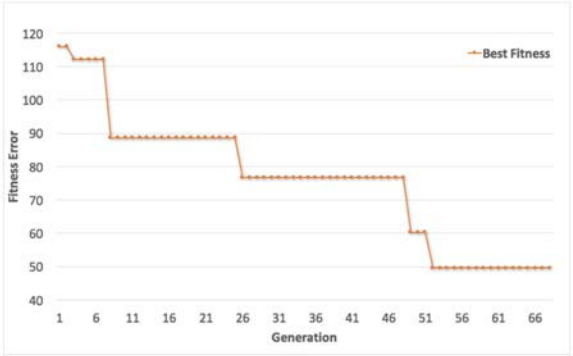
Aim 2. Evaluate clusters of GPUs to explore and optimize the parameters of large-scale brain circuit models.

Large-scale parameter exploration and optimization

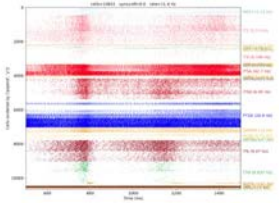


Initial candidate





Final candidate



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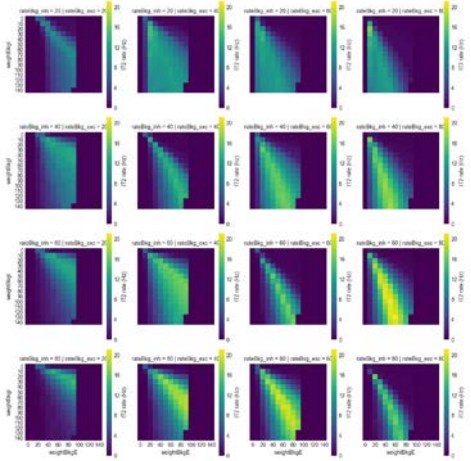
Large-scale parameter exploration and optimization



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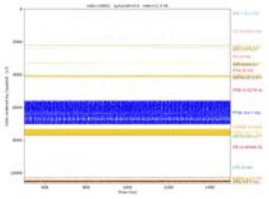

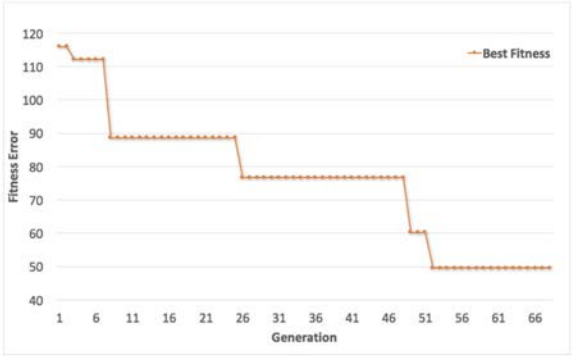

Final candidate