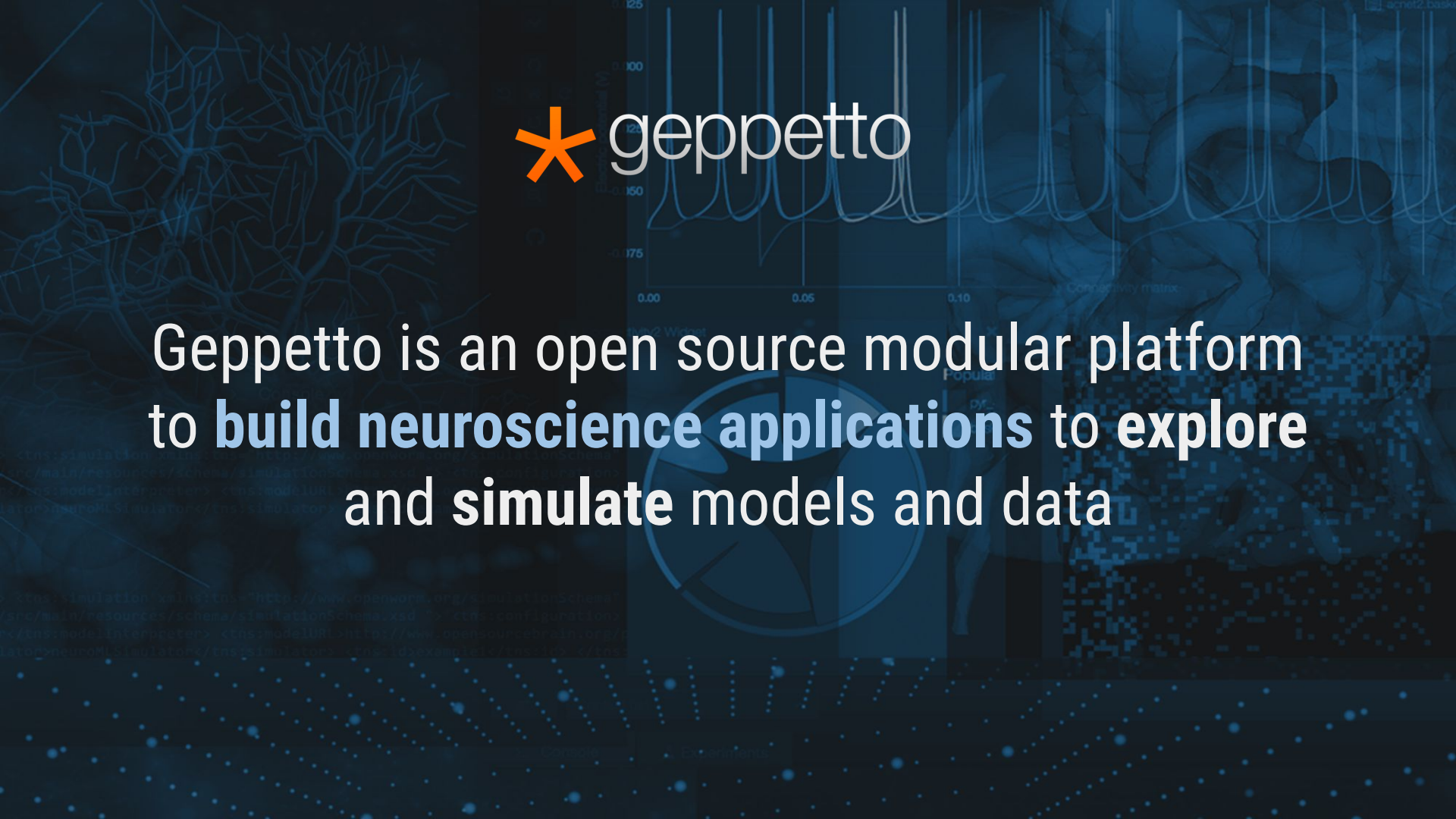
Matteo Cantarelli
MetaCell Founder and CTO
Geppetto Architect and Coordinator
OpenWorm Founder

OSB Meeting, Alghero
September 9th 2019


geppetto
Geppetto is an open source modular platform to **build neuroscience applications** to **explore** and **simulate** models and data

What can Geppetto applications do?

- Visualize **neuroscience data** in the browser
  - Computational Neuroscience Models (NeuroML, NetPyNE, NEURON, *)
  - Morphologies reconstructions (SWC, OBJ, Collada, *)
  - Electrophisiology recordings (NWB:N 2, HDF5, *)
  - Neuroimaging (MRI, Electromicroscopy via DICOM, NIFTI, DZI, *)

- **Run simulations** from the browser
  - Connect to an external simulator
  - Create your computational experiments, record model variables via the UI
  - Set model parameters
  - Simulate on remote clusters (e.g. San Diego Neuroscience Gateway)

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What else can Geppetto applications do?

- Connect your application directly to a Python Kernel
  - Use the Geppetto Jupyter Backend to create an application that talks directly to the Python Kernel. Call Python methods and evaluate Python instructions from Javascript.
- Synchronize the user interface with your Python models
  - Edit your models from the user interface or programmaticaly via an embedded Jupyter Notebook
- Connect to external data sources to provide data and models (e.g. Neo4j, AberOWL, *)
- Simplify the **exploration** of data and models
  - Every model loaded in Geppetto is indexed and easily searchable.
- Facilitates **reproducibility** of workflows
  - The entire user interface works on top of an API layer. Every user action corresponds to an API command easy to inspect and reproduce.

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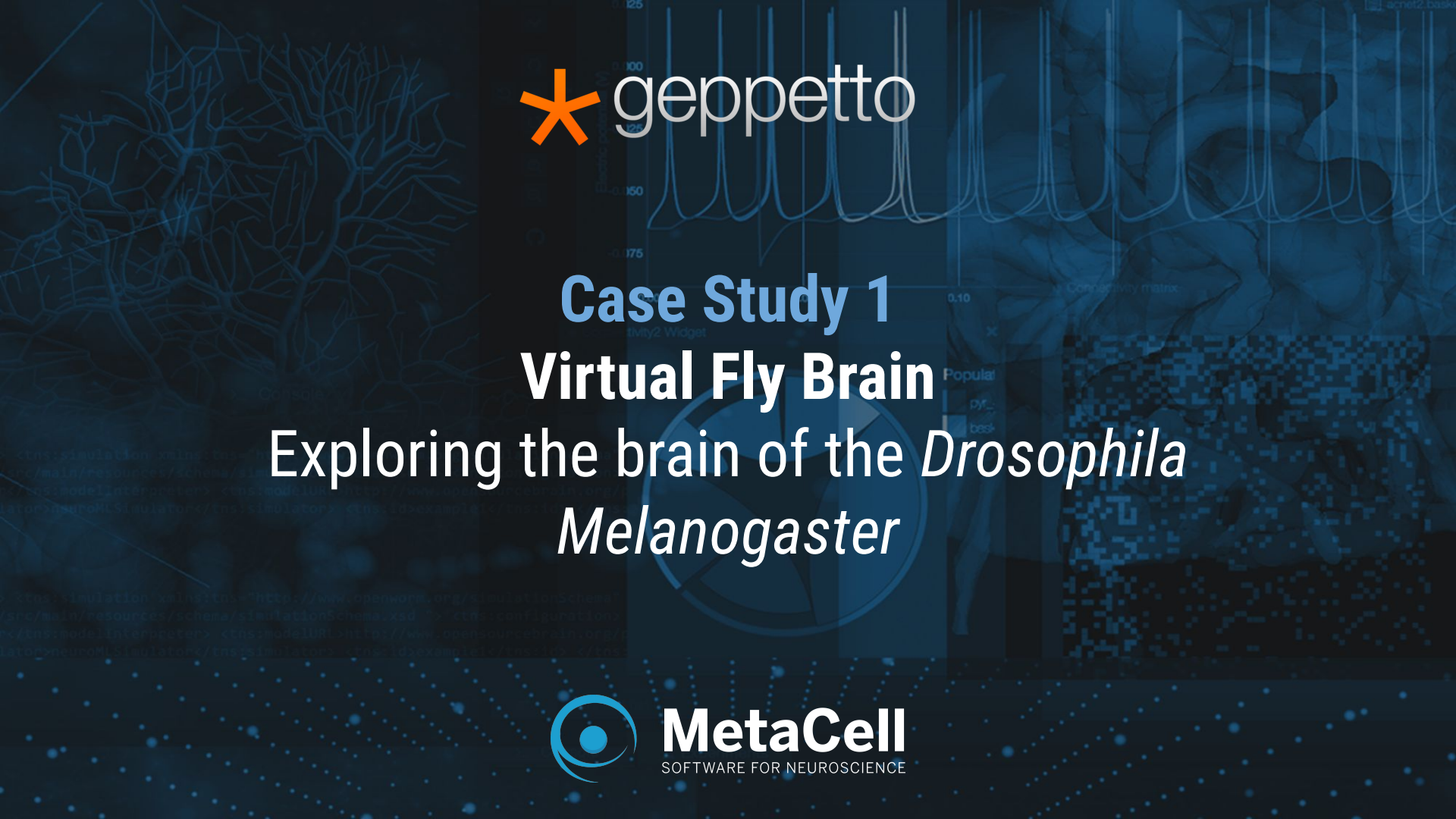
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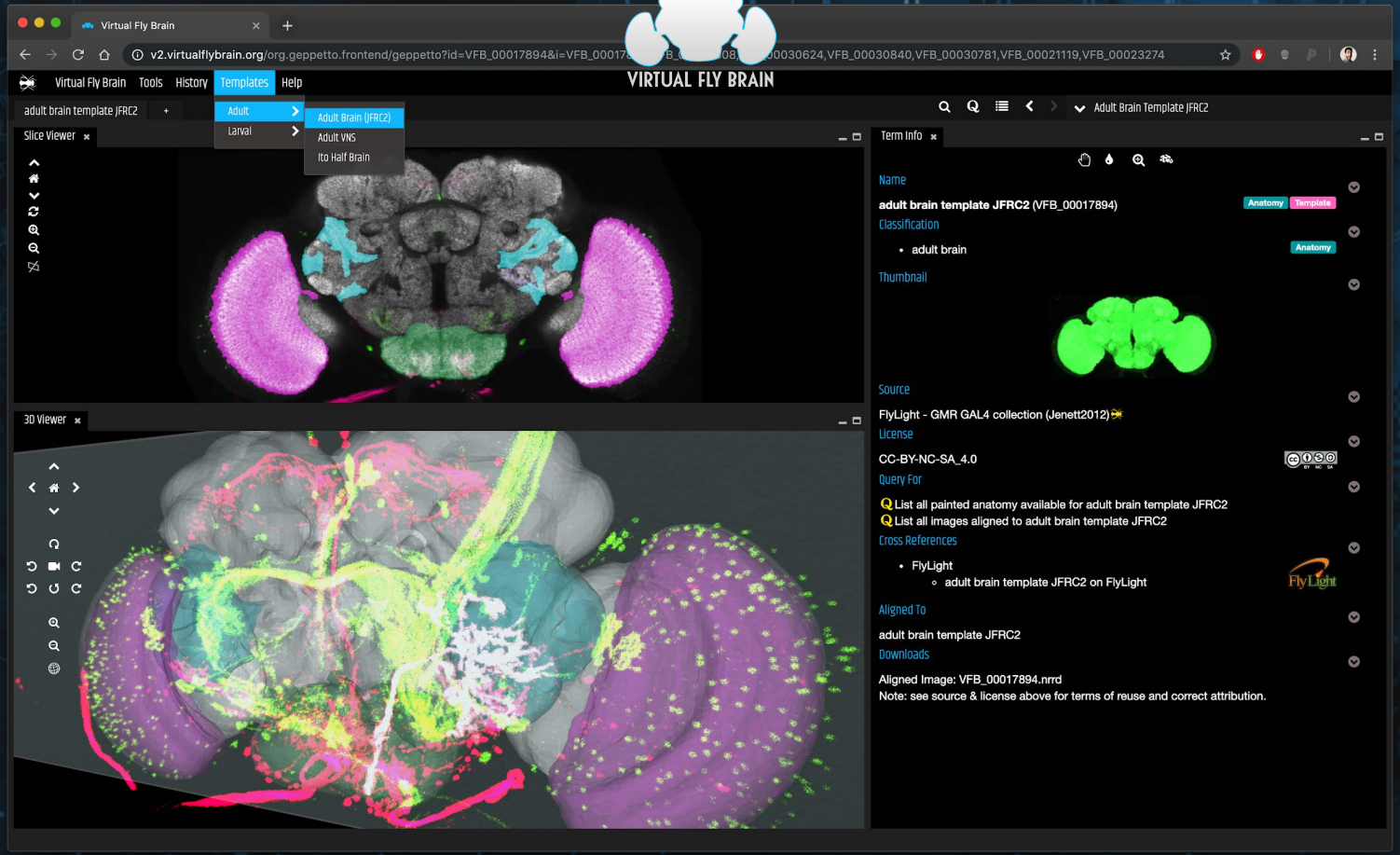
Case Study 1
Virtual Fly Brain
Exploring the brain of the *Drosophila Melanogaster*
MetaCell
SOFTWARE FOR NEUROSCIENCE


Virtual Fly Brain
v2.virtualflybrain.org/org.geppetto.frontend/geppetto?id=VFB_00017894&i=VFB_00017
00030624,VFB_00030840,VFB_00030781,VFB_00021119,VFB_00023274
VIRTUAL FLY BRAIN
Virtual Fly Brain
Tools
History
Templates
Help
adult brain template JFRC2
Adult
Larval
Adult Brain (JFRC2)
Adult VNS
Ito Half Brain
Adult Brain Template JFRC2
Slice Viewer
3D Viewer
Term Info
Name
adult brain template JFRC2 (VFB_00017894)
Anatomy
Template
Classification
adult brain
Anatomy
Thumbnail
Source
FlyLight - GMR GAL4 collection (Jenett2012)
License
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Query For
List all painted anatomy available for adult brain template JFRC2
List all images aligned to adult brain template JFRC2
Cross References
FlyLight
adult brain template JFRC2 on FlyLight
FlyLight
Aligned To
adult brain template JFRC2
Downloads
Aligned Image: VFB_00017894.nrrd
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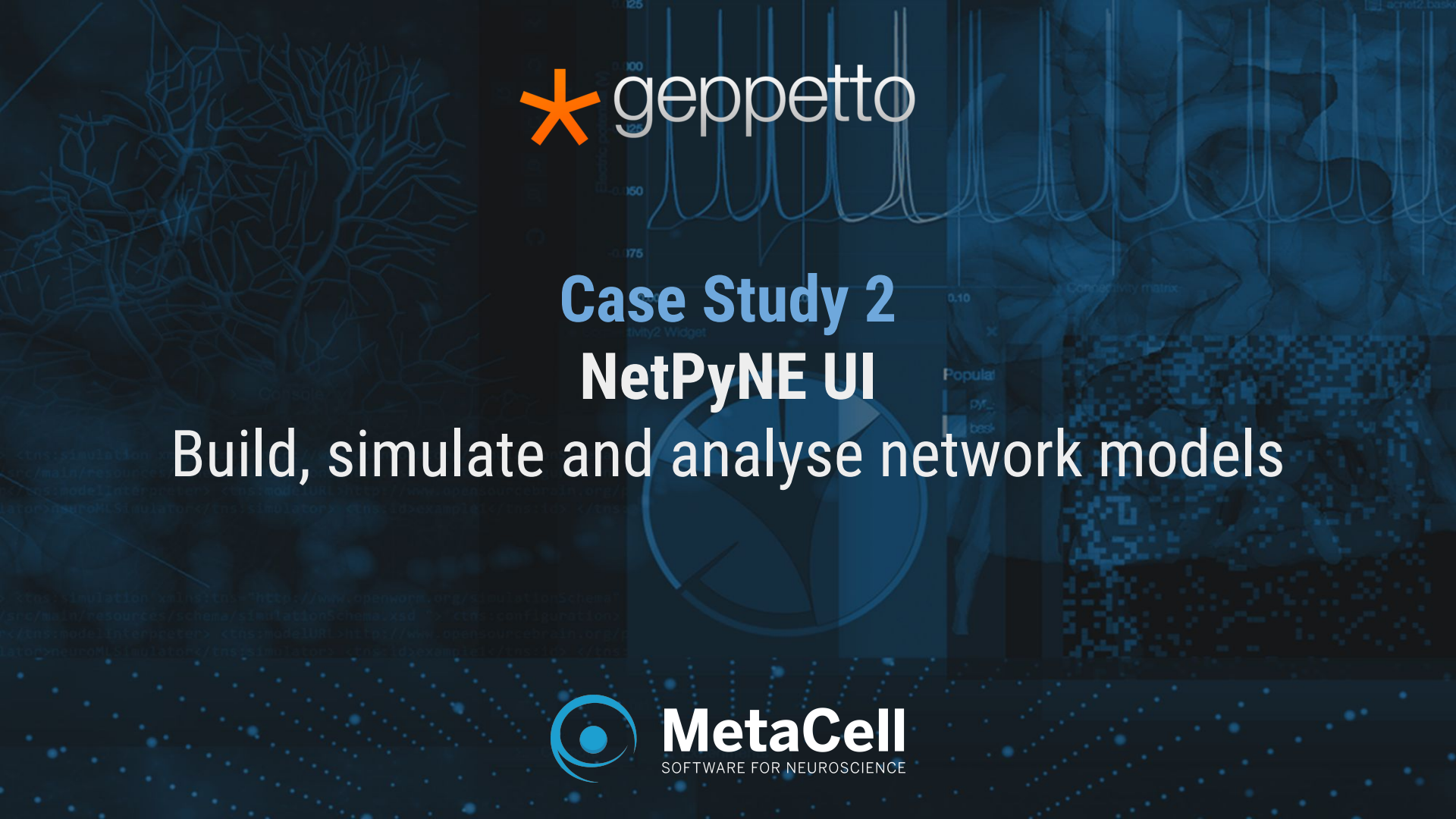
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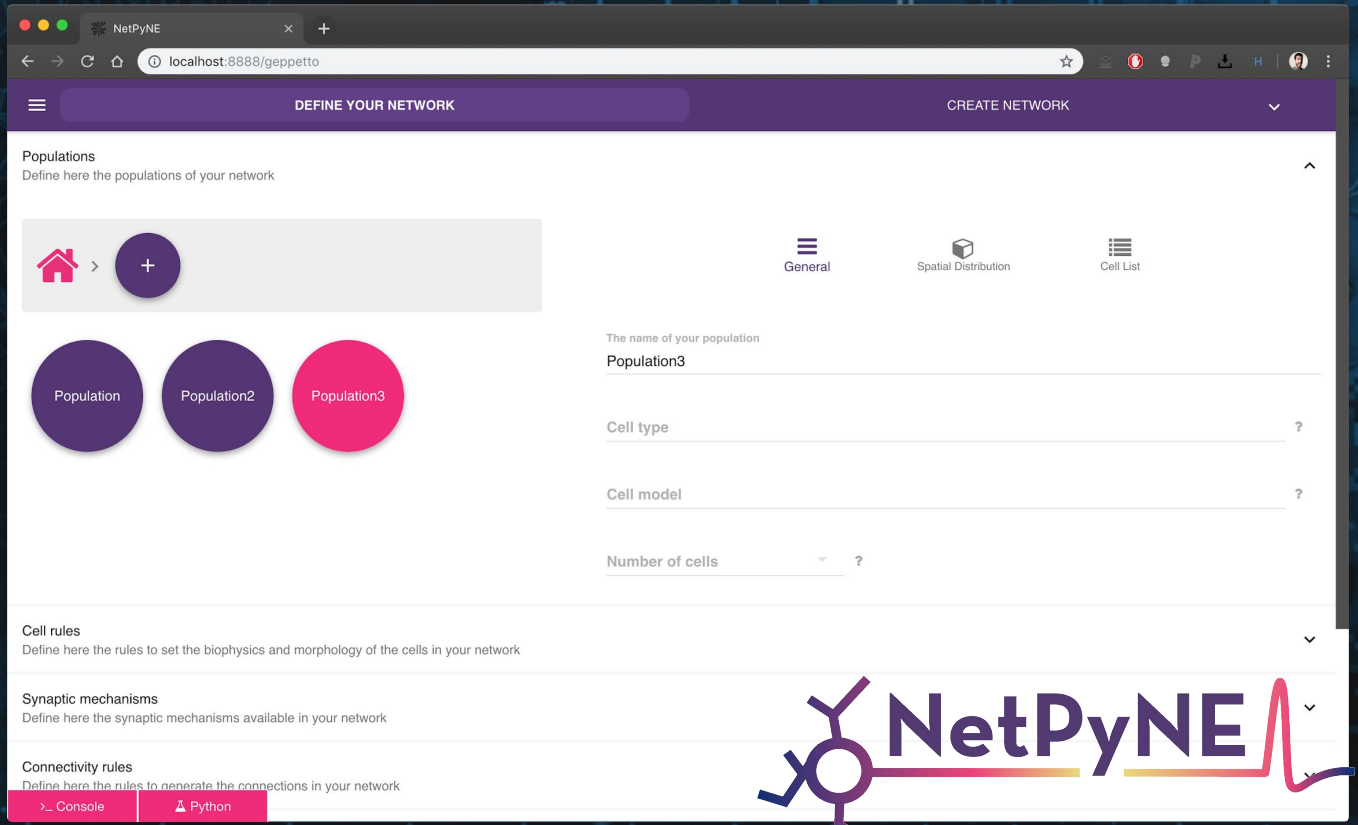
Case Study 2
NetPyNE UI
Build, simulate and analyse network models
MetaCell
SOFTWARE FOR NEUROSCIENCE

What is NetPyNE?

- A Python package to facilitate the development, simulation and analysis of biological neuronal networks in NEURON
- Primarily developed by Salvador Dura Bernal at SUNY
- High Level Specification
  - Specifications are provided in a standardized, declarative Python format (JSON-like, lists and dicts).
    - Populations: cell type, number of neurons or density, spatial extent, ...
    - Cell properties: morphology, biophysics, implementation, …
    - Synaptic mechanisms: time constants, reversal potential, implementation,
    - Stimulation: Spike generators, current clamps, spatiotemporal properties, …
    - Connectivity rules: conditions of pre- and post-synaptic cells, different functions, …
    - Simulation configuration: duration, saving and analysis, graphical output, ...
  - Clear separation of parameters from implementation code.
  - Error checking and suggestions to facilitate model definition.



NetPyNE

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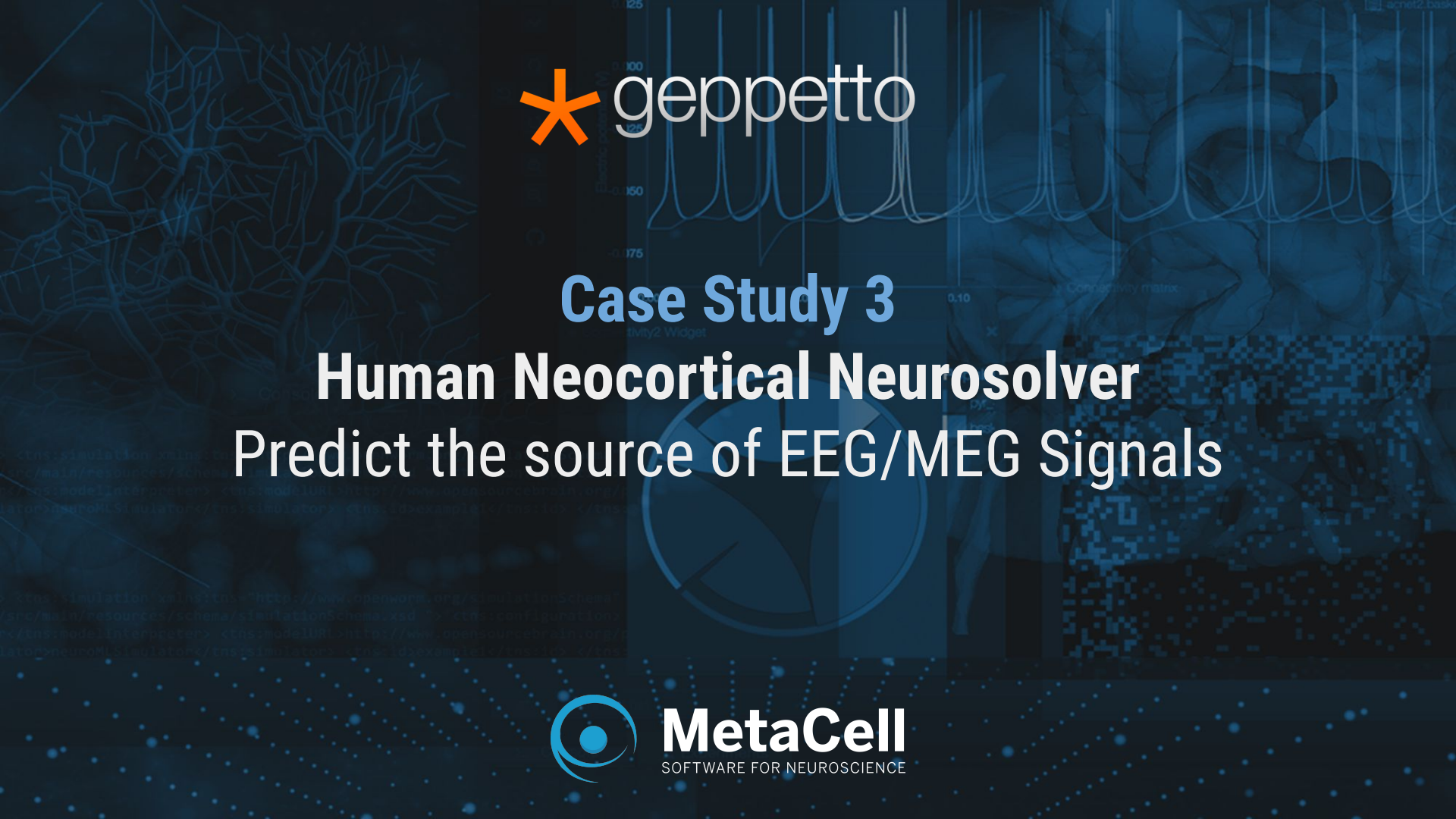
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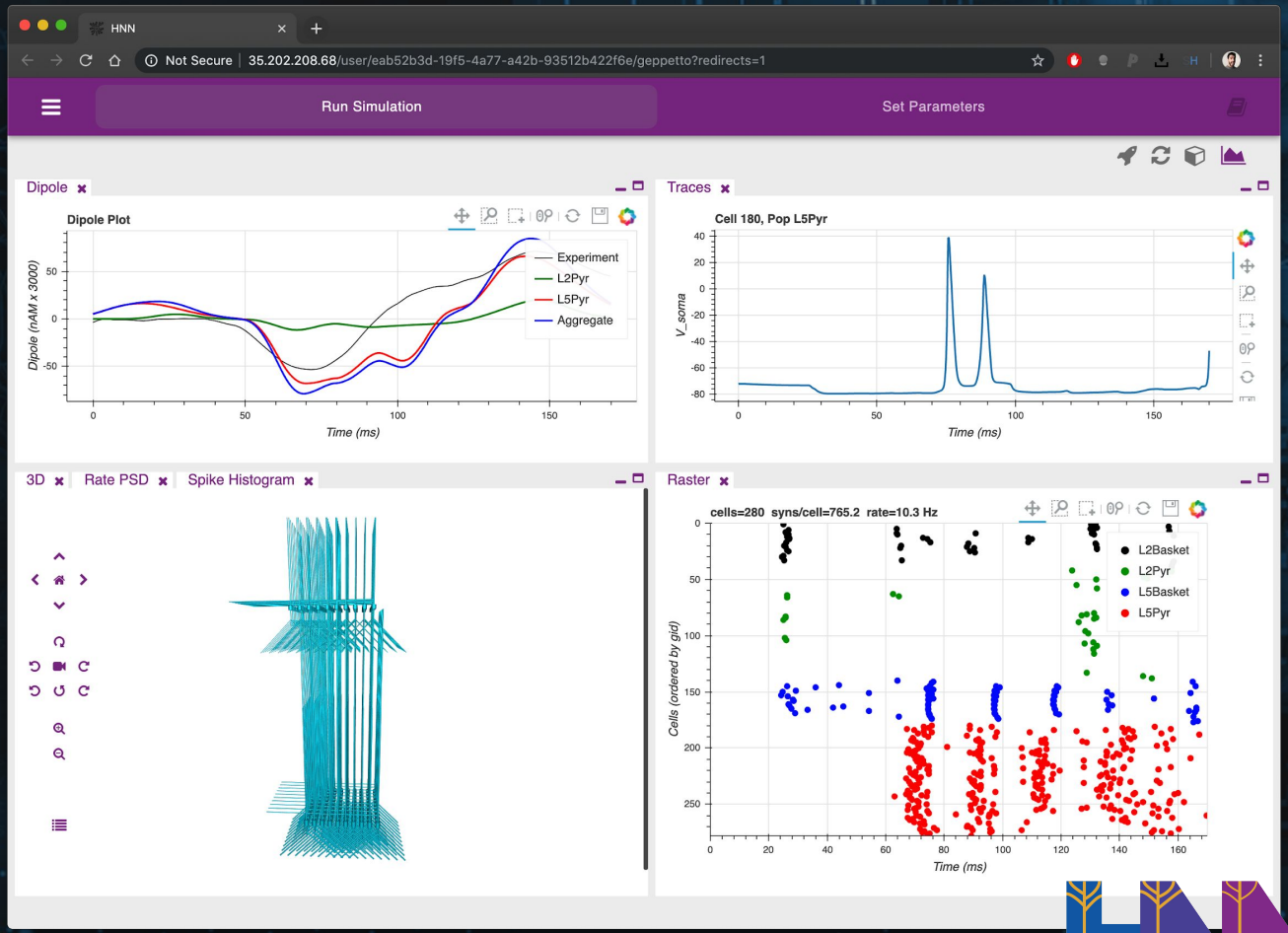
Case Study 3
Human Neocortical Neurosolver
Predict the source of EEG/MEG Signals
MetaCell
SOFTWARE FOR NEUROSCIENCE

What is the Human Neocortical Neurosolver?

- A computational neural model that simulates the electrical activity of the neocortical cells and circuits that generate the primary electrical currents underlying EEG/MEG recordings.
- HNN gives researchers and clinicians the ability to test and develop hypotheses on the circuit mechanism underlying their EEG/MEG data in an easy-to-use environment
- Principal Investigator: Prof. Stephanie Jones at Brown University
- New version implemented using NetPyNE
- Preprint: https://www.biorxiv.org/content/10.1101/740597v2.full



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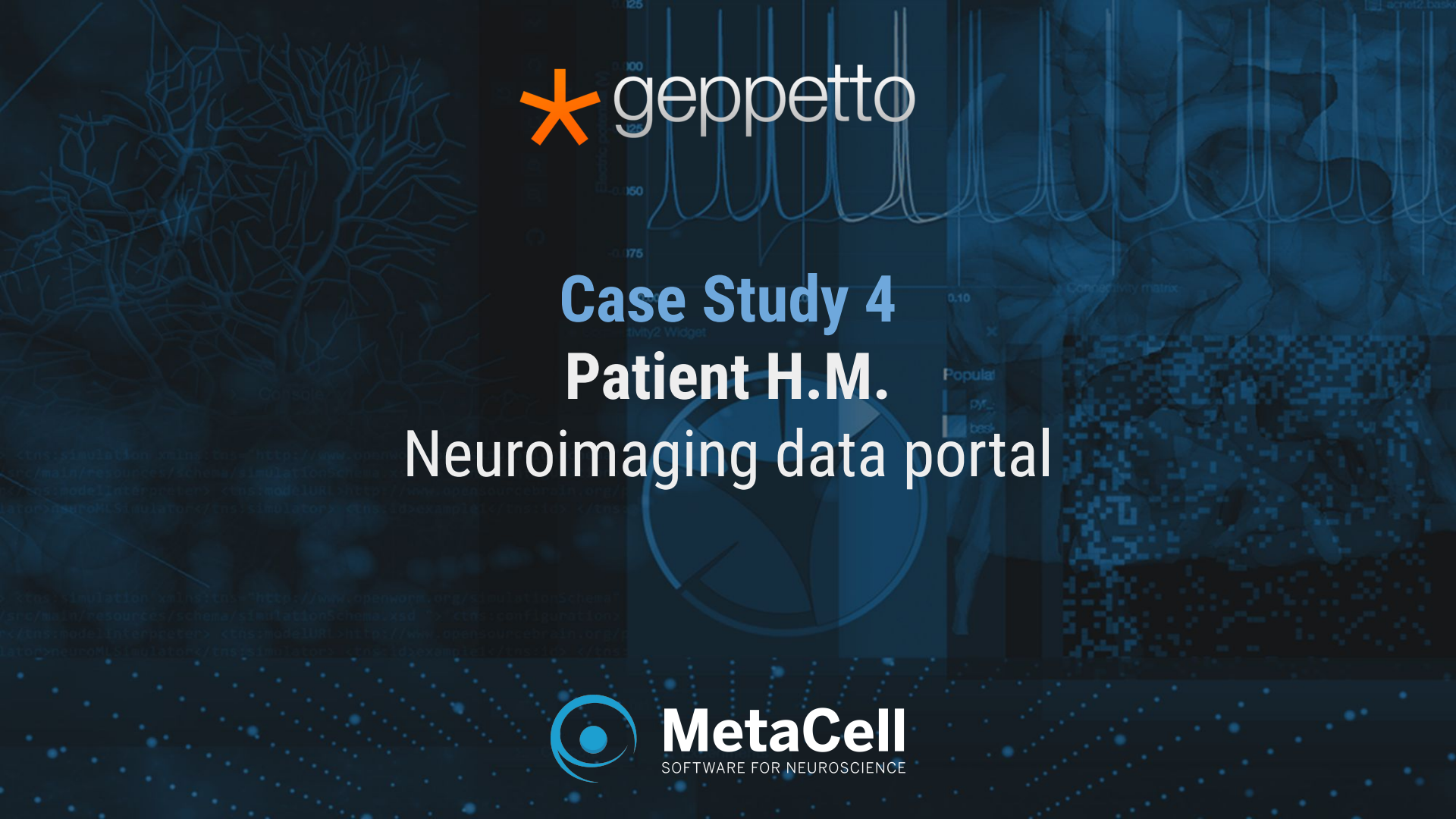
HNN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Case Study 4
Patient H.M.
Neuroimaging data portal
MetaCell
SOFTWARE FOR NEUROSCIENCE

Patient H.M.

Not Secure | 54.183.154.48/atlas

PATIENTHM.org

THE STORY DATA PORTAL HISTOLOGICAL ATLAS THE BRAIN OBSERVATORY

Home The Story The Brain Data Portal Histological Atlas The Brain Observatory

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Case Study 5

Open Source Brain

Web based simulation of computational neuroscience models in NeuroML

MetaCell

SOFTWARE FOR NEUROSCIENCE

OPEN SOURCE BRAIN

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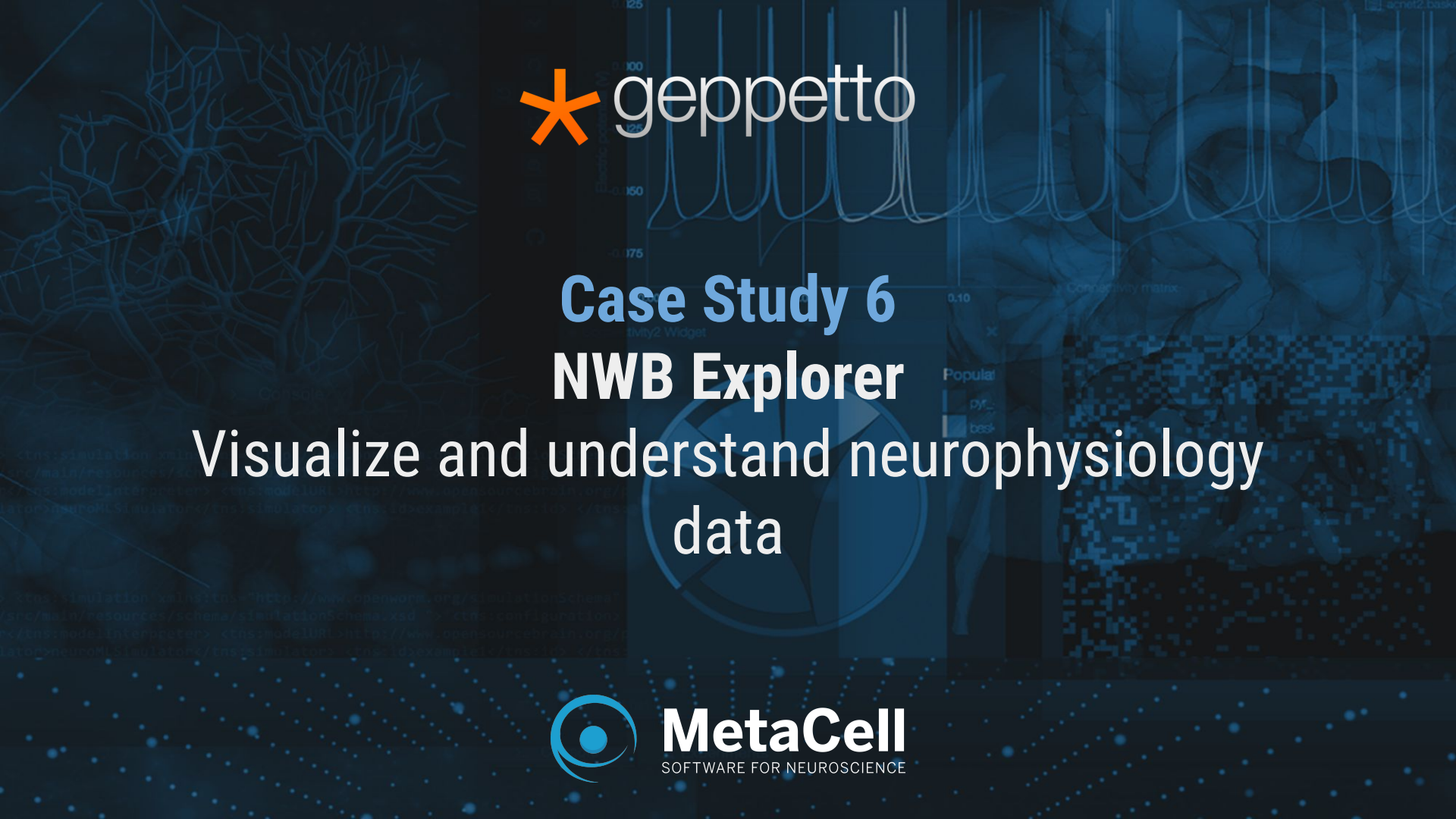
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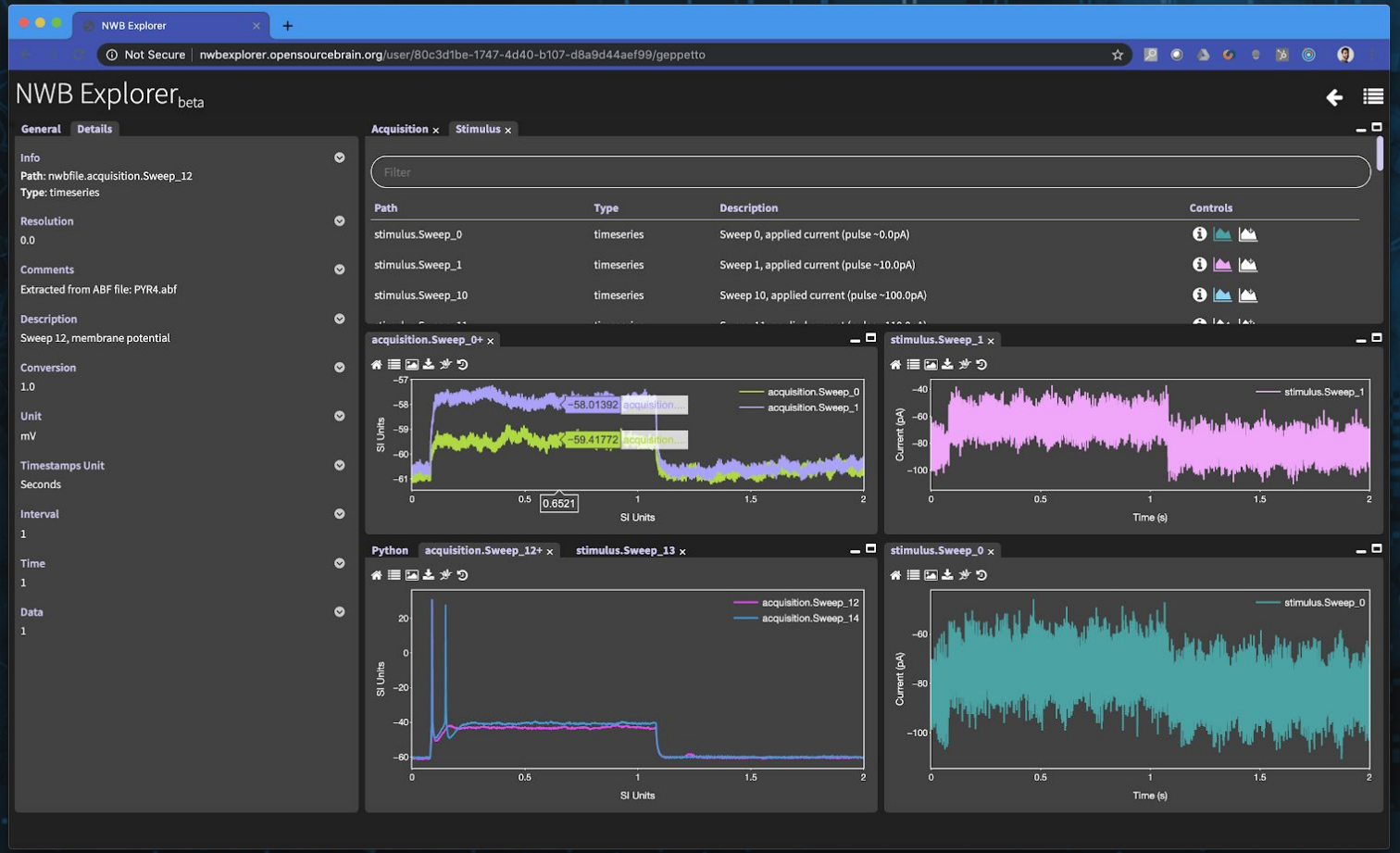
Case Study 6
NWB Explorer
Visualize and understand neurophysiology data
MetaCell
SOFTWARE FOR NEUROSCIENCE


NWB Explorer
Not Secure | nwbexplorer.opensourcebrain.org/user/80c3d1be-1747-4d40-b107-d8a9d44aef99/geppetto
NWB Explorer beta
General
Details
Info
Path: nwbfile.acquisition.Sweep_12
Type: timeseries
Resolution
0.0
Comments
Extracted from ABF file: PYR4.abf
Description
Sweep 12, membrane potential
Conversion
1.0
Unit
mV
Timestamps Unit
Seconds
Interval
1
Time
1
Data
1
Acquisition
Stimulus
Filter
Path
Type
Description
Controls
stimulus.Sweep_0
timeseries
Sweep 0, applied current (pulse ~0.0pA)
stimulus.Sweep_1
timeseries
Sweep 1, applied current (pulse ~10.0pA)
stimulus.Sweep_10
timeseries
Sweep 10, applied current (pulse ~100.0pA)
acquisition.Sweep_0+
acquisition.Sweep_0
acquisition.Sweep_1
-58.01392
-59.41772
0.6521
SI Units
stimulus.Sweep_1
Current (pA)
Time (s)
Python
acquisition.Sweep_12+
stimulus.Sweep_13
acquisition.Sweep_12
acquisition.Sweep_14
stimulus.Sweep_0

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Open Source Brain

Search

Home
Learn
Sign in

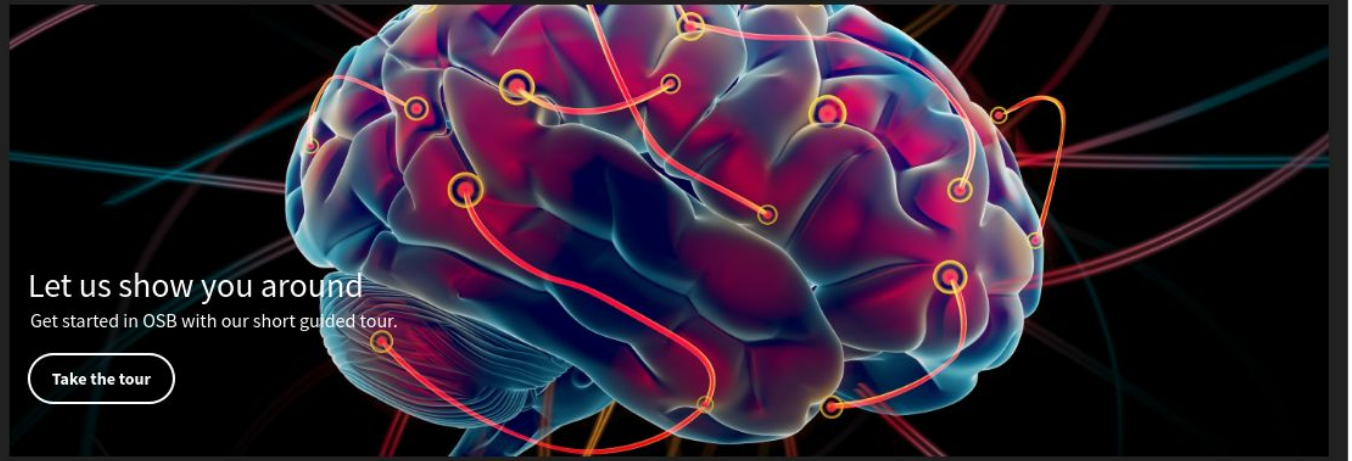
Create new model...

Add Dataset...

Your workspaces

Auditory Cortex
Hodgkin Huxley
Test 1

Welcome to Open Source Brain. Let's do some science.

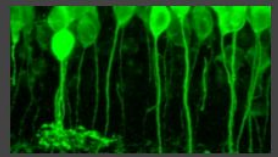


Checkout existing neurophysiology recordings

Pick a dataset to get started!

Ferguson et al.

Allen Cell DB Release 2



Browse existing repositories

Pick a category to filter the repositories

Datasets

Models

Notebooks

Open Source Brain

Open Source Brain | Experiment | Window | Help | Primary Auditory Cortex

Morphologies

Model Description

Network: network_ACnet2

Description

A small scale network model with 60 cells based on Dave Beeman's Auditory Cortex model

*View the original **NeuroML 2** source file*

Populations

baskets_12: 12 cell of type bask

pyramidals_48: 48 cell of type pyr_4_sym

Cells

bask | pyr_4_sym

Ion channels

Ca_pyr | Kahp_pyr | Kdr_bask | Kdr_pyr | LeakConductance_bask | LeakConductance_pyr | Na_bask | Na_pyr

Synapses

AMPA_syn | AMPA_syn_inh | GABA_syn | GABA_syn_inh

Inputs

BackgroundRandomIClamps | BackgroundRandomIClamps | BackgroundRandomIClamps | BackgroundRandomIClamps | BackgroundRandomIClamps | BackgroundRandomIClamps | BackgroundRandomIClamps | BackgroundRandomIClamps |

Experiment

COMPLETED

Simulator: NEURON

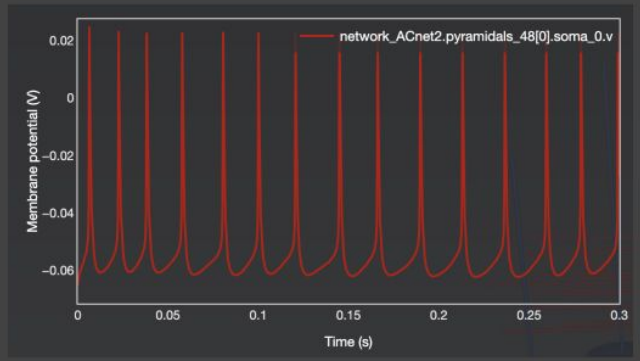
Duration: 250ms

Timestep: 0.25ms

Recorded Variables

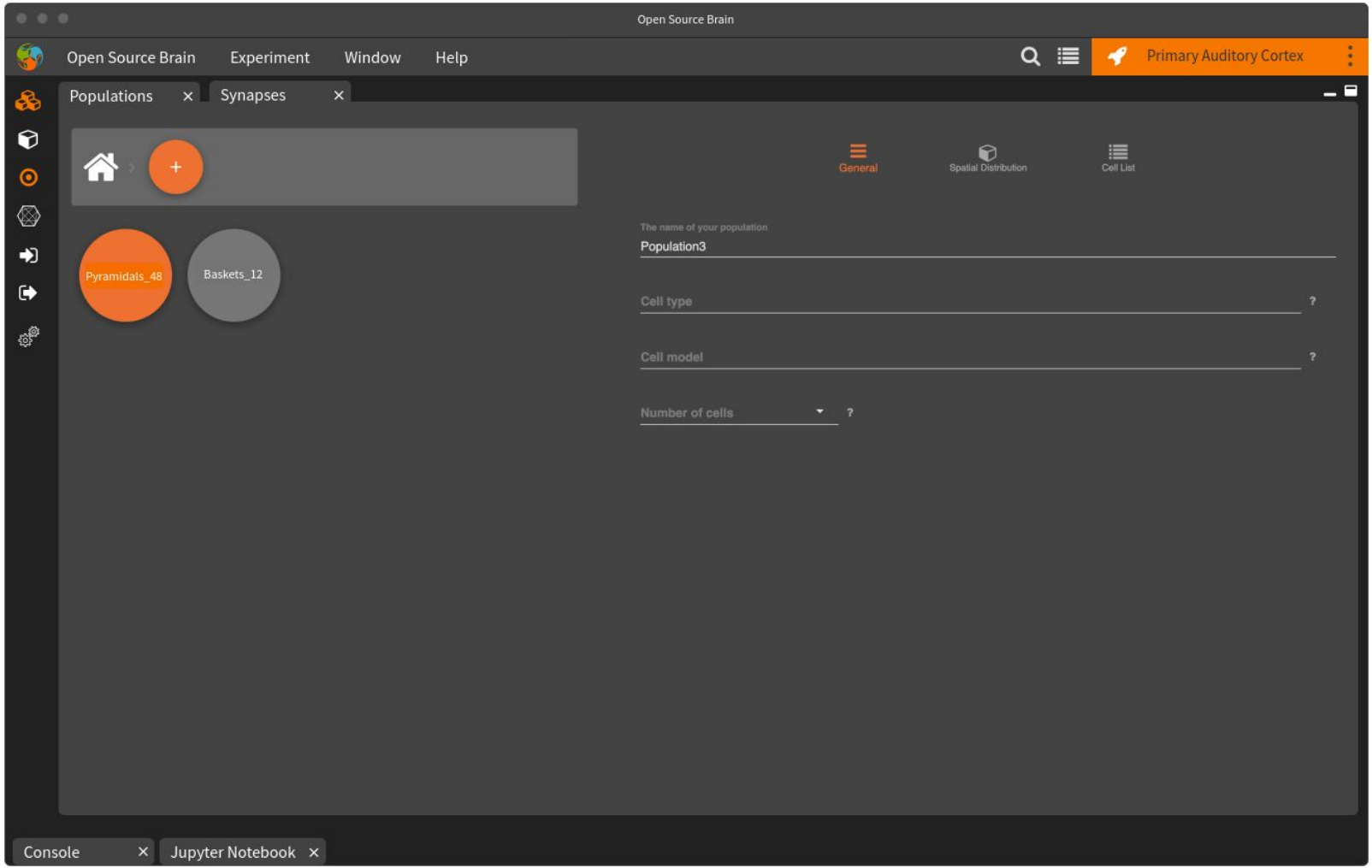
Parameters Set

Plot 1 | Plot 2



Connectivity

Console | Jupyter Notebook


Open Source Brain
Open Source Brain
Experiment
Window
Help
Primary Auditory Cortex
Populations
Synapses
General
Spatial Distribution
Cell List
Pyramidals_48
Baskets_12
The name of your population
Population3
Cell type
Cell model
Number of cells
Console
Jupyter Notebook

Geppetto Architecture

- Data/Model agnostic web-based architecture to efficiently lazy load data and stream it in a compressed fashion
- Defines an internal **abstraction** to represent hierarchical models and data
- **Modular backend** to extend supported models, simulators and data source
- Generic and extensible **widgets** framework to expand frontend visualization capabilities

  [3D CANVAS, PLOT, CONNECTIVITY, STACK VIEWER, MRI VIEWER, BIG IMAGE VIEWER, AUDIO/MOVIE PLAYER, ...]
- Generic and extensible **components** framework to define customer user interfaces

  [SEARCH, CONTROL PANEL, SIMULATION CONTROLS, EXPERIMENTS CONTROLS, DASHBOARD, BASIC UI CONTROLS, ...]

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Is Geppetto a platform or an application?

- **Geppetto is an open-source platform to build neuroscience applications**
- Every Geppetto application can be hosted privately or publicly
- Every Geppetto application can be fully customised
  - **Decide what your interface will look like**
  - Decide what data, models and simulator you want to use
  - Choose only the components and widgets you need

Whether you only need to visualize some surface models or create a system that enables visualization and simulation of integrated data and models Geppetto will save you between two and five years of development.

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How to get started?

- Read the paper! http://**paper**.geppetto.org
- **Pick your backend**
  - Java
  - Python Jupyter
  - Python Django
- **Clone geppetto-application and customise it to build your own application**
  - This is your template, here you define your **custom user interface and custom workflows**
- Reuse any of the pre-existing 20+ UI components
  - E.g. 3D Viewer, Connectivity Analysis, Plotting widget, MRI Viewer, etc.
- Reuse any of the pre-existing backend modules
  - E.g. NeuroML, NEURON, SWC support, etc.

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Open Source, MIT Licensed

20+ Contributors

32 repositories

42 releases

7+ years of development

Automated Travis+Docker+Pupetter based testing

http://www.geppetto.org | paper.geppeto.org | docs.geppetto.org | live.geppetto.org | git.geppetto.org | board.geppetto.org | blog.geppetto.org

Applications built with Geppetto so far...

Open Source Brain (University College London)

Virtual Fly Brain (EBI/Uni Cambridge/Edinburgh/MRC)

NetPyNE UI (State University of New York)

Patient H.M. (The Brain Observatory)

HNN UI (Brown University)

NWB Explorer (MetaCell/University College London/OpenWorm)

Scidash (Arizona State University)

NEURON UI (State University of New York/Yale)

WormSim (OpenWorm)

Advantages

- **Unified platform for computational modeling, visualization and data exploration**
- Reused by multiple groups and projects
  - More users, more testing, more features, less bugs.
  - Open Source features developed for one Geppetto application are available to all Geppetto applications.
- Solutions to common problems are reused and optimised
  - Abstract meta-meta-model definition, streaming of data, scriptable UI, lazy loading, data visualization, data compression, automated unit and UI testing, etc.
- Enterprise architecture for better scalability and robustness
- Growing open source community

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Acknowledgements

Core Contributors

Matteo Cantarelli
Giovanni Idili
Adrian Quintana Perez
Jesus Martinez
Filippo Ledda
Facundo Rodriguez
Matt Earnshaw
Boris Marin

See full list of contributors:
contributors.geppetto.org

Supporting Groups

MetaCell, Ltd. LLC
Open Source Brain and UCL
Virtual Fly Brain and EBI-EMBL
NeuroSim Lab and SUNY
Wellcome Trust
OpenWorm Foundation

JOIN US!

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Thanks for your time!

Questions? Get in touch!

matteo@metacell.us
@tarelli