COMPUTATIONAL ANALYSIS OF PRIMATE VISION

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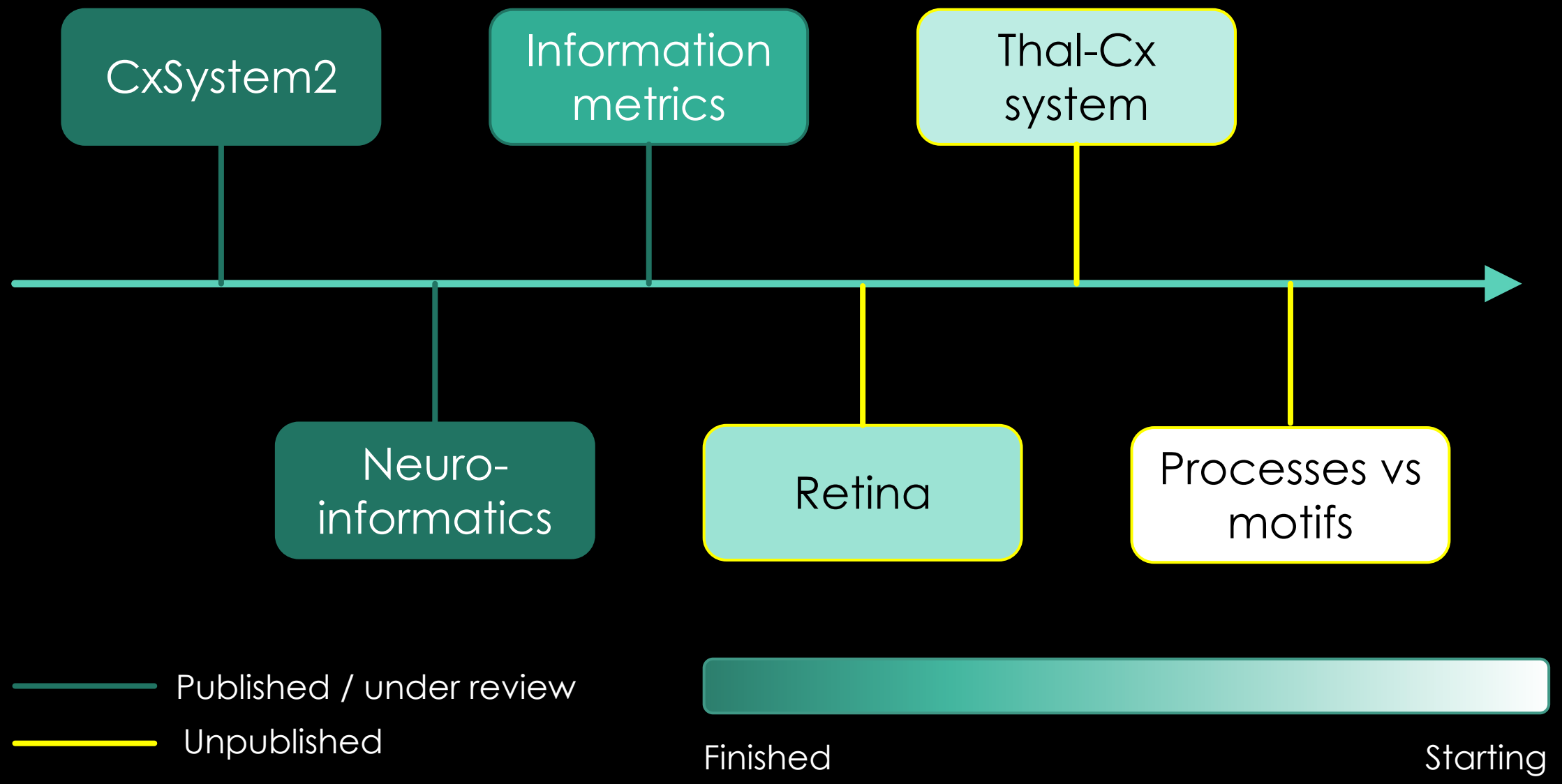
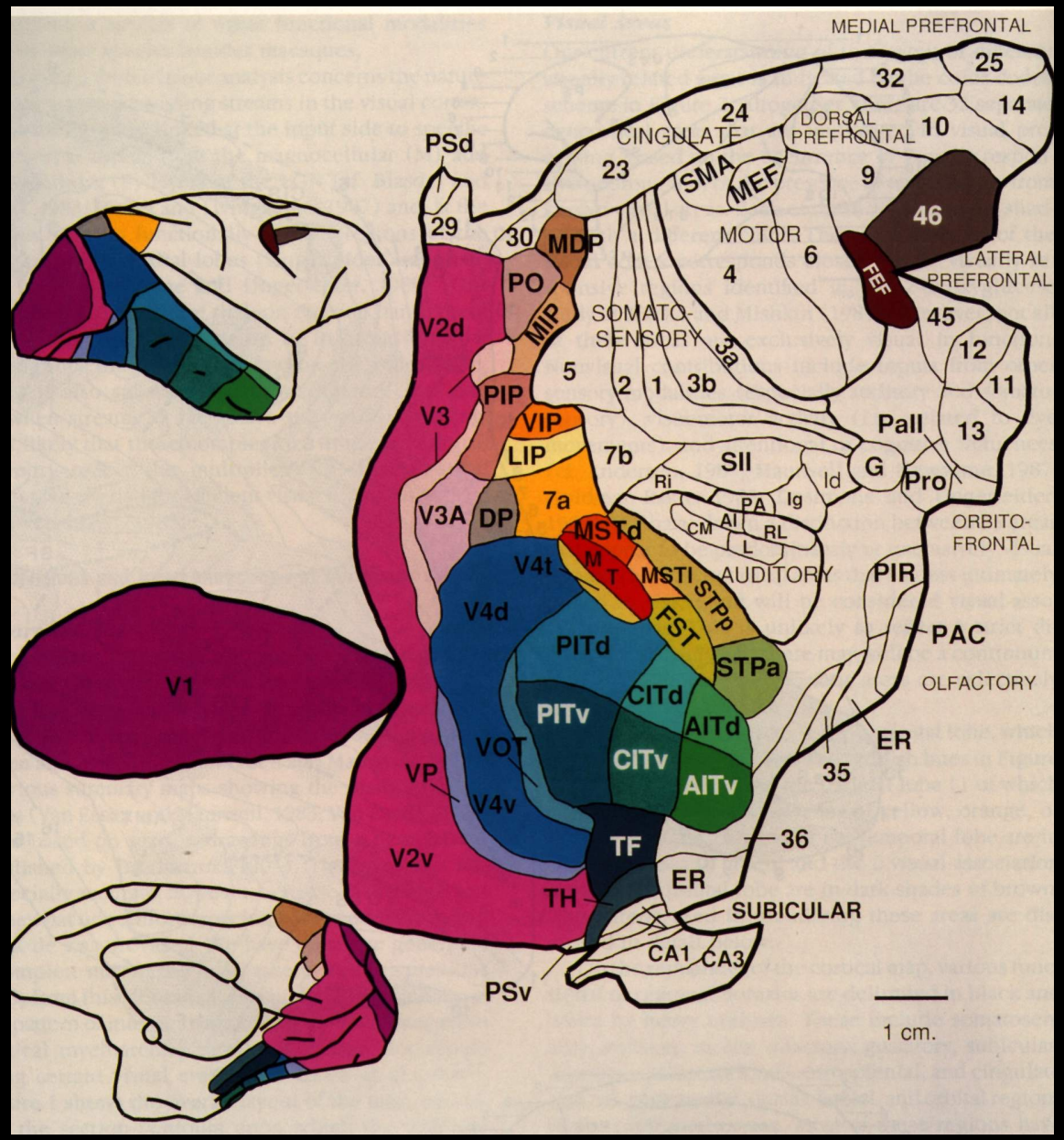
DO BRAINS COMPUTE?

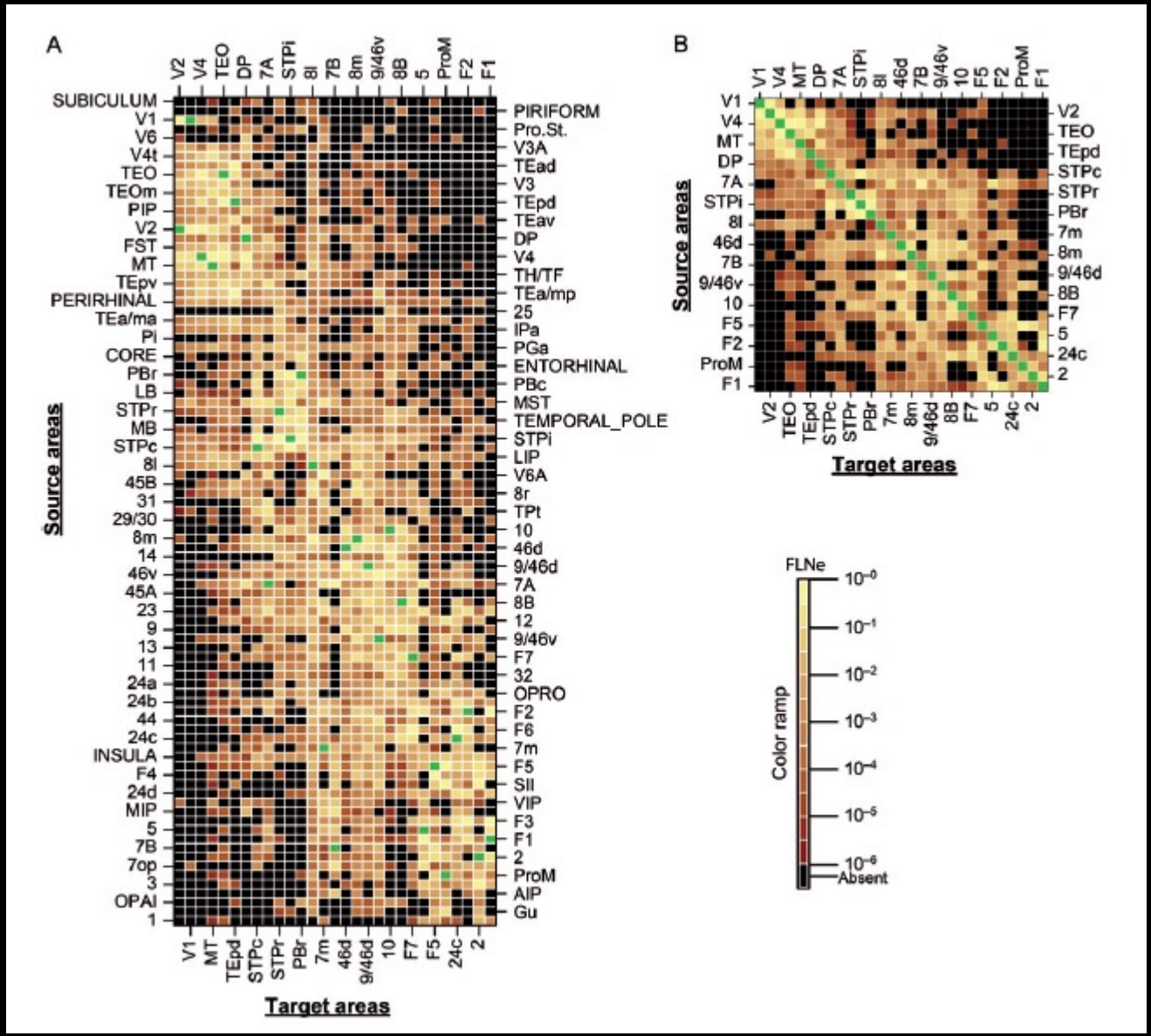
WHY BIOLOGICAL REALISM?

WHY COMPUTATION?


CxSystem2
Information metrics
Thal-Cx system
Neuro-informatics
Retina
Processes vs motifs
Published / under review
Unpublished
Finished
Starting



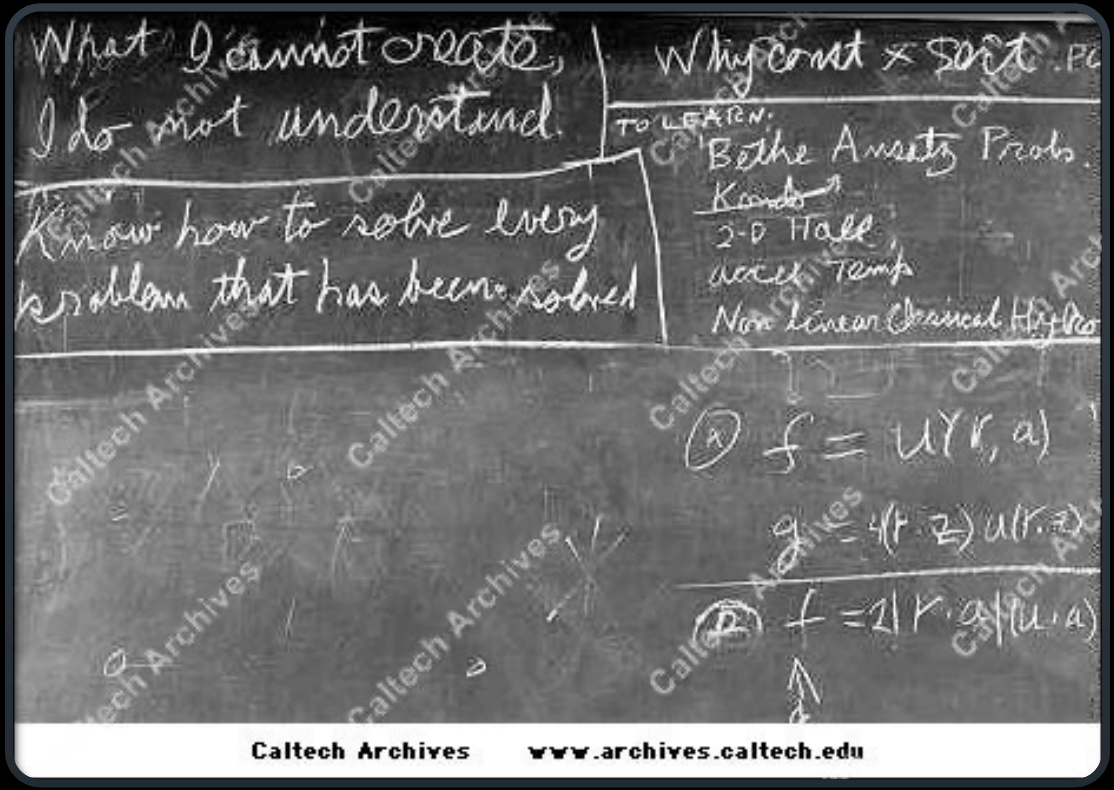
Felleman & Van Essen, Cerebral Cortex 1991



Markov et al., Cerebral Cortex 2014

PRIMATES AND MICE

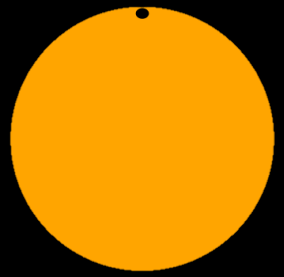
- MICE ARE ACCESSIBLE TO MOLECULAR METHODS AND GENETIC ENGINEERING
- RETINA, FOVEA, VISUAL CORTICAL ORGANIZATION AND VISUAL BEHAVIOR VERY DIFFERENT
- PRIMATE CX HIERARCHY STILL BETTER UNDERSTOOD



- Richard Feynman

WHAT I CANNOT
CREATE
I DO NOT
UNDERSTAND

$\neq$



```python
from __future__ import division
import numpy as np
import matplotlib.pyplot as plt
import pdb

pi=np.pi
x = np.arange(-pi,pi,pi/100)
y = np.exp(1j*x)

# pdb.set_trace()

fig, ax = plt.subplots()
ax.fill(np.real(y), np.imag(y), 'orange')
ax.fill(np.real(y)/20,19/20+np.imag(y)/25,'black')
ax.axis('equal')
plt.axis('off')
plt.show()
```

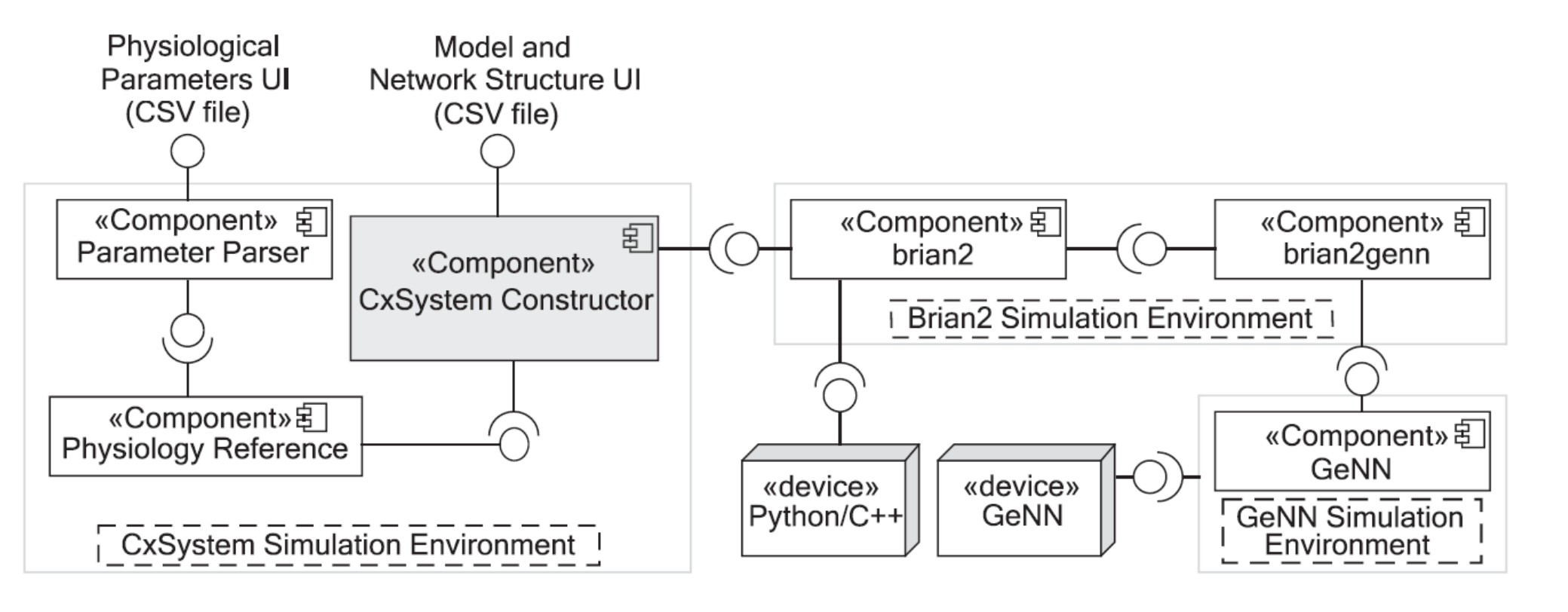
COMPLEX CODE HINDER DEVELOPMENT

CXSYSTEM2

Design principles: Flexibility, Simplicity

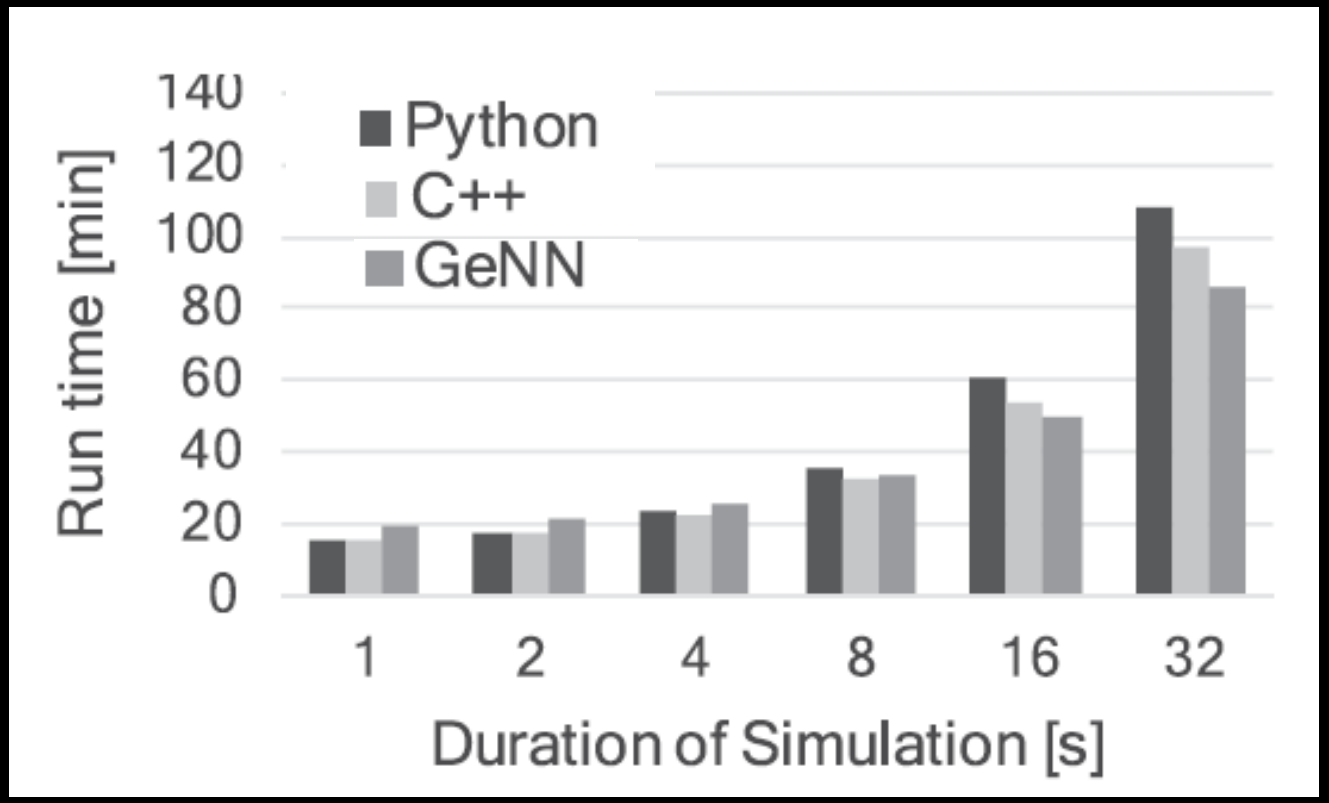
Built on top of Brian2

CSV FILE INTERFACE TO SIMULATION



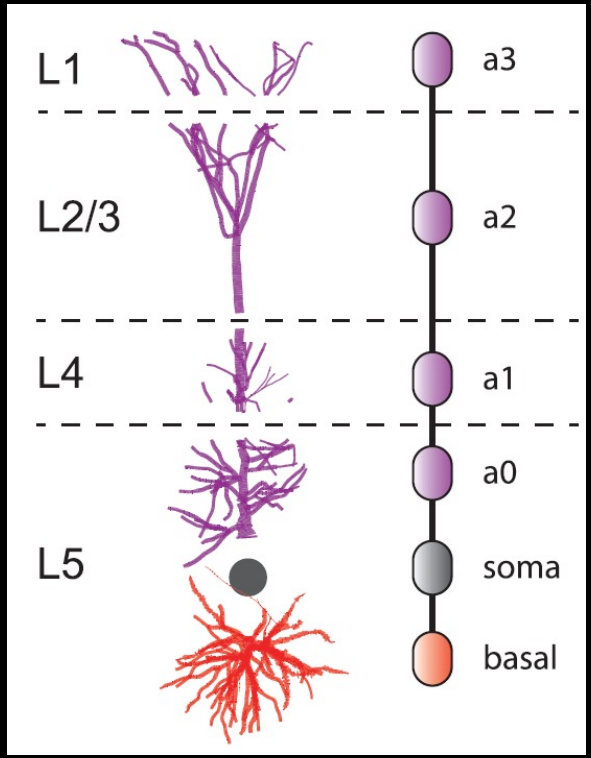
Andalibi et al., Neural Computation 2019

PYTHON, C++, GENN AND CLUSTER OPTIONS



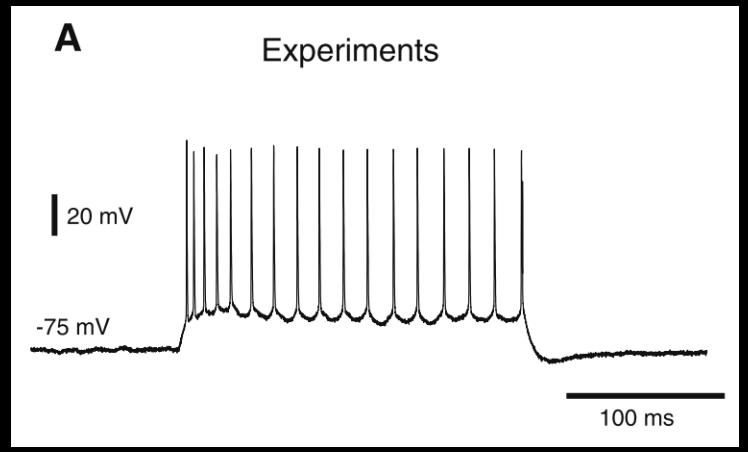
Andalibi et al., Neural Computation 2019

SUPPORT FOR OLIGOCOMPARTMENTAL MODELS



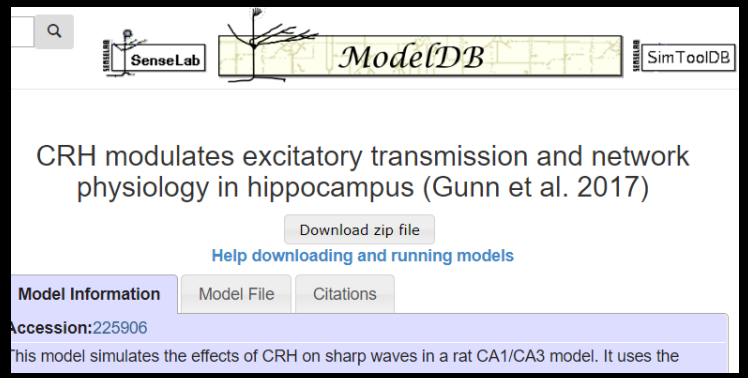
Hokkanen et al., Neural Computation 2019

NEURODYNLIB USE CASES



Analyze experimental traces
(eFel, BluePyOpt)

Neurodynlib → CxSystem



Import existing models

NEUROINFORMATICS
FRAME FOR SELECTION OF PARAMETERS

OXFORD

Cerebral Cortex, June 2020;30: 3483–3517

doi: 10.1093/cercor/bhz322
Advance Access Publication Date: 2 January 2020
Feature Article

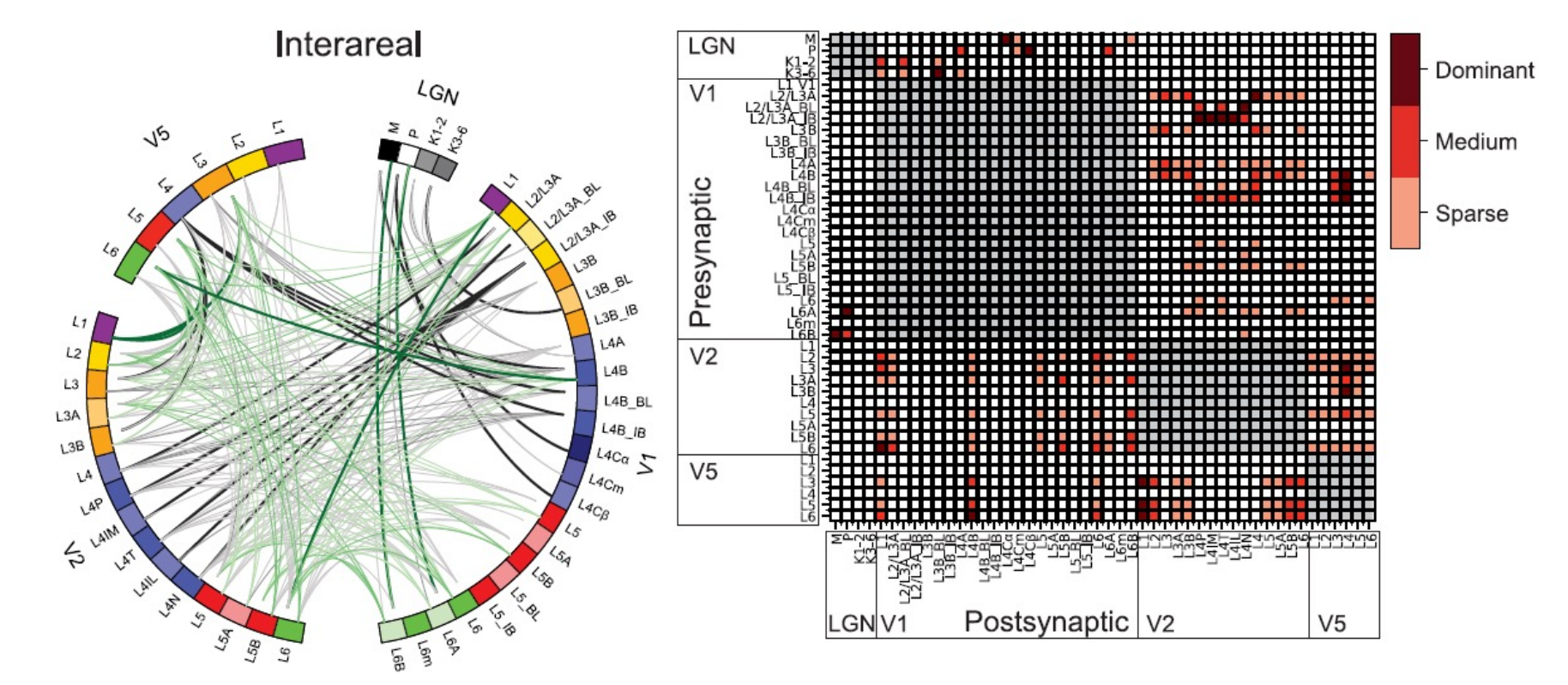
FEATURE ARTICLE

Anatomy and Physiology of Macaque Visual Cortical Areas V1, V2, and V5/MT: Bases for Biologically Realistic Models

Simo Vanni[1,2], Henri Hokkanen[1,2], Francesca Werner[1,2,3], and Alessandra Angelucci[4]

INTERAREAL CONNECTIVITY

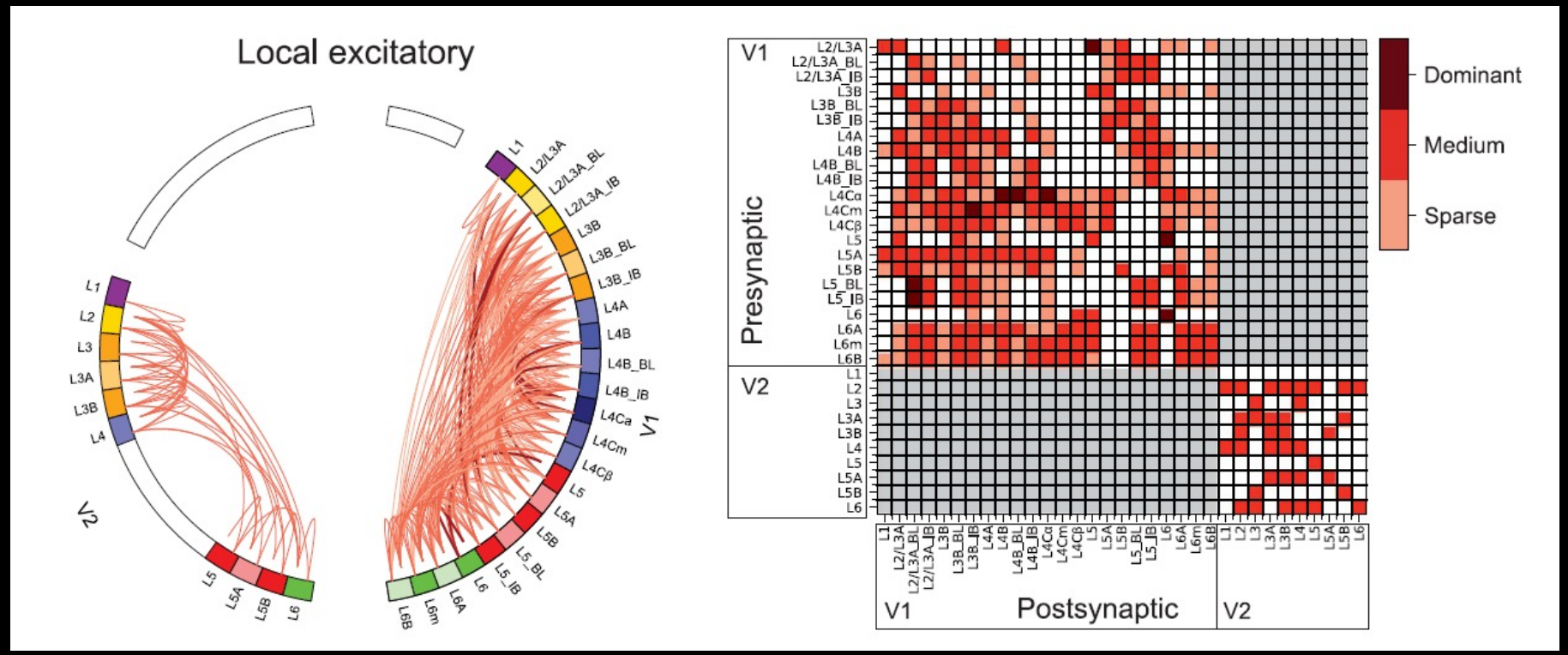
MAJOR PATHWAYS ARE WELL-KNOWN



Vanni et al., Cerebral Cortex 2020

LOCAL CONNECTIVITY

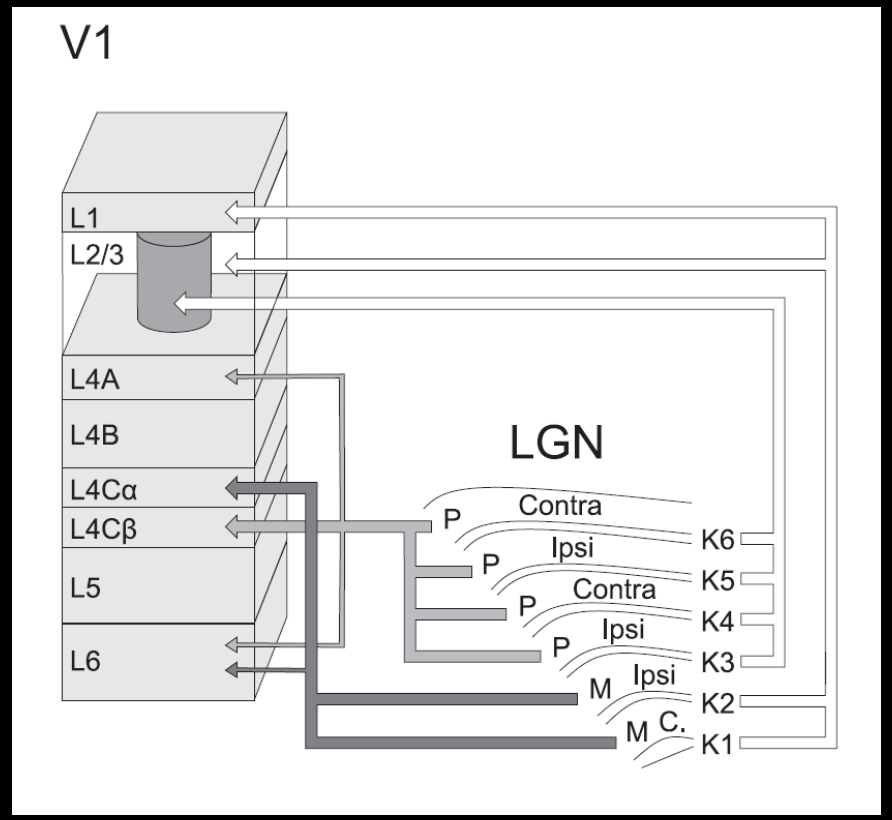
KNOWN ONLY FOR V1, LESS SO FOR INHIBITORY CELL TYPES, V2 AND V5



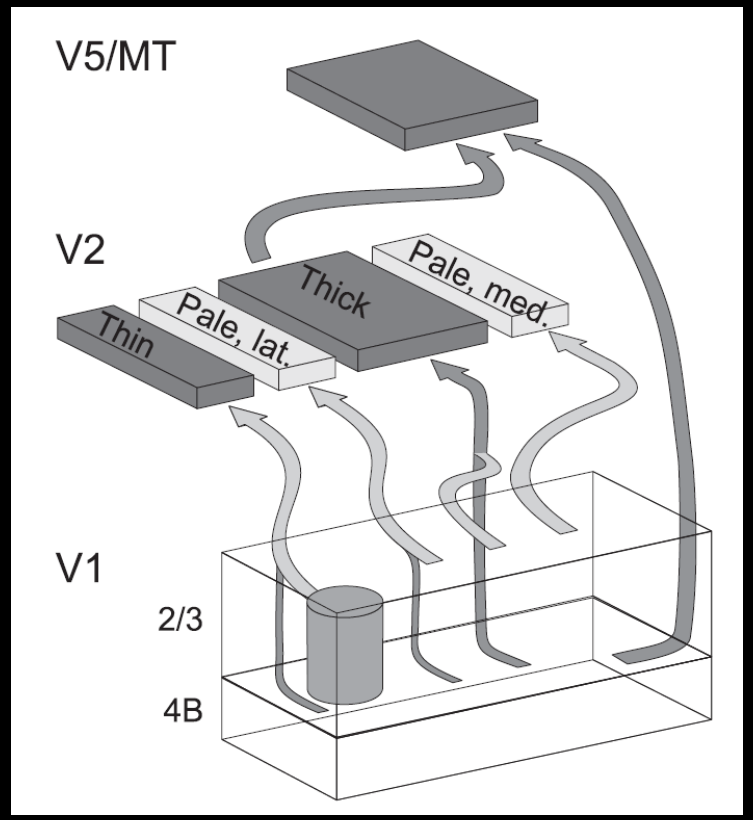
Vanni et al., Cerebral Cortex 2020

INTRICATE PARALLEL PATHWAYS

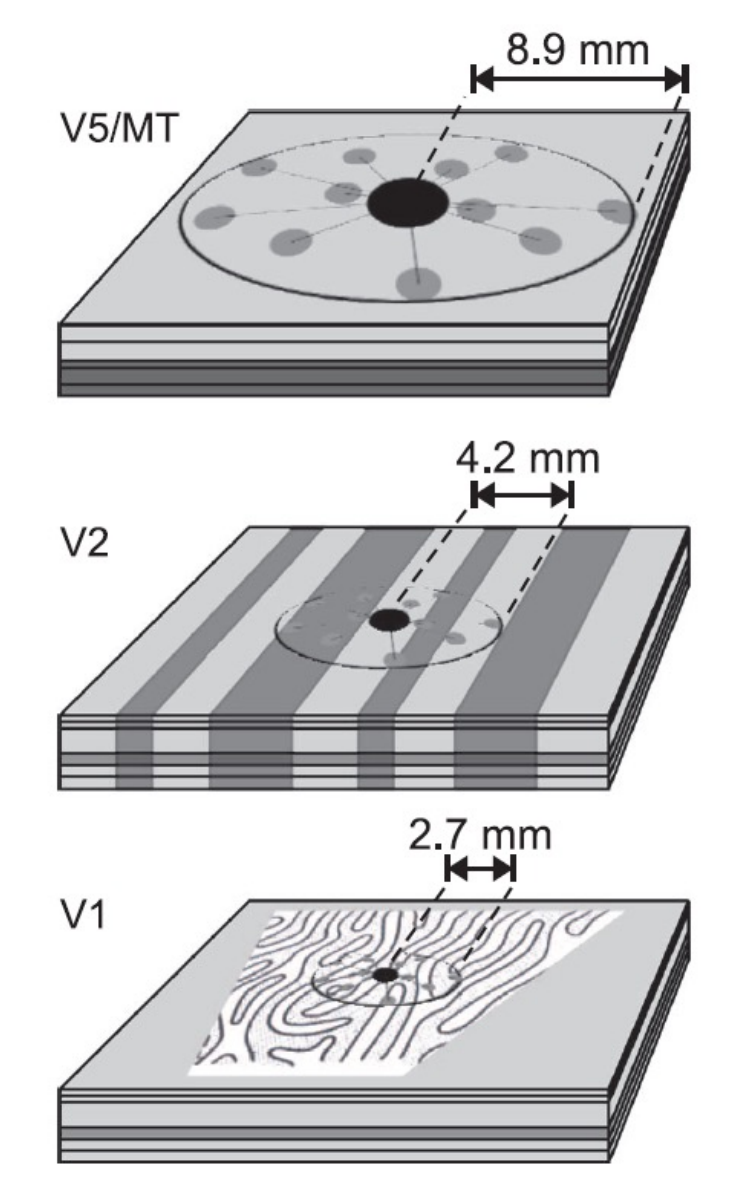
LGN => V1



V1 => V2, V5

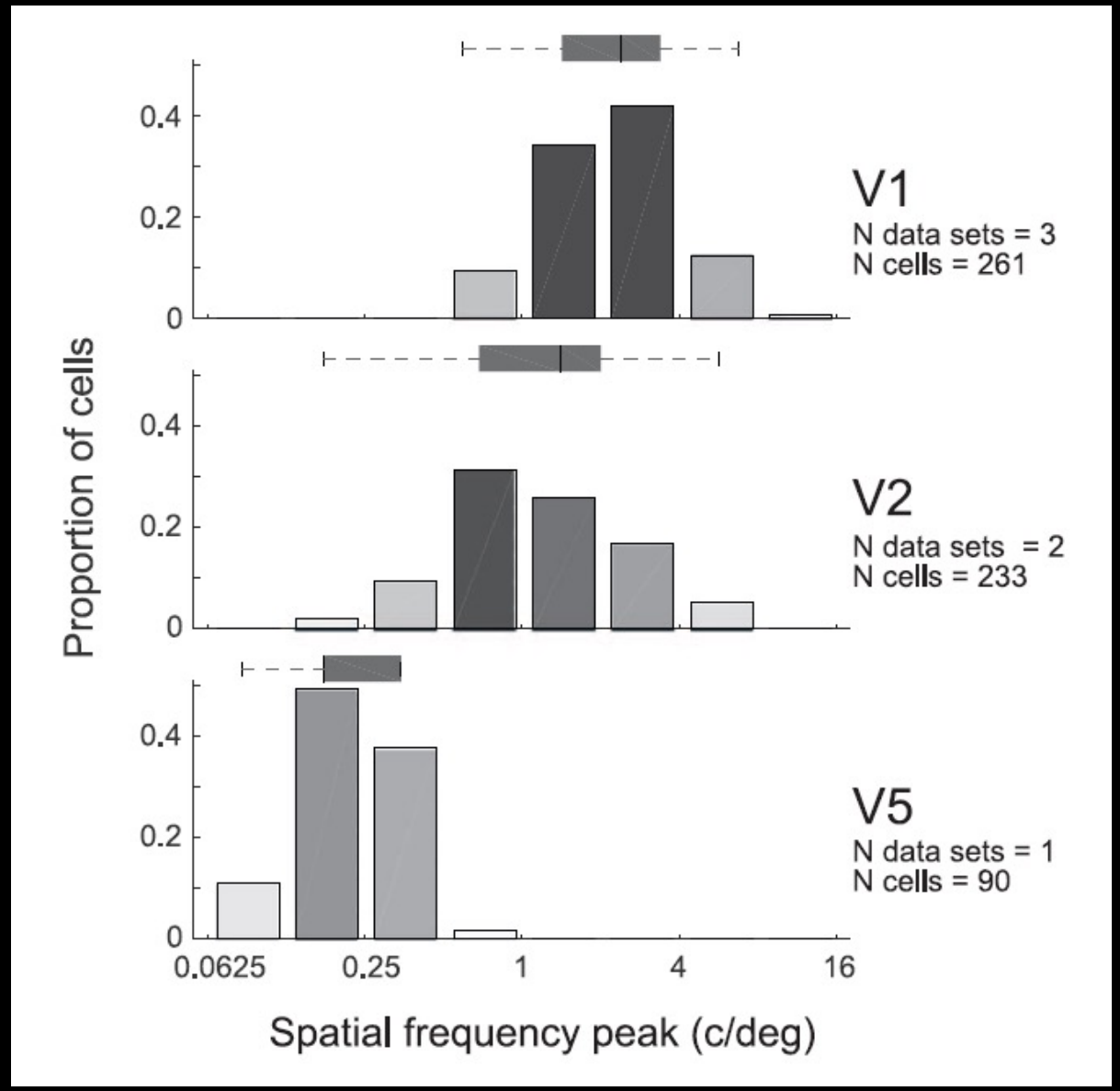


Vanni et al., Cerebral Cortex 2020



Vanni et al., Cerebral Cortex 2020

HORIZONTAL, PATCHY CONNECTIONS EXTEND LONGER DISTANCES IN HIGHER AREAS



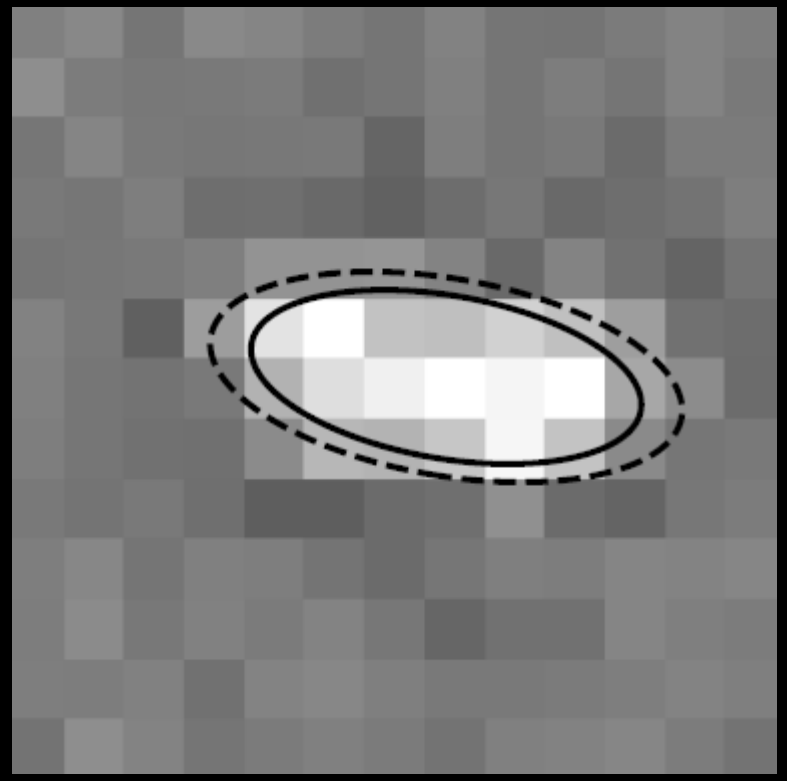
SOME VISUAL STIMULUS TUNING PARAMETERS CLEARLY DISCRIMINATE THE V1, V2 AND V5

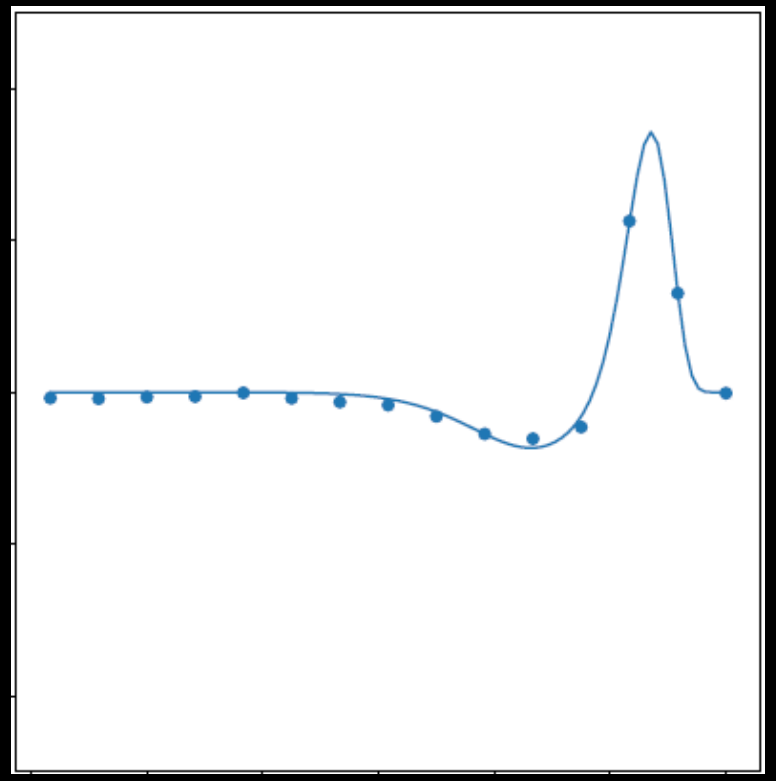
Vanni et al., Cerebral Cortex 2020

RETINA MODEL

VISUAL STIMULI NEED REASONABLE PREFILTER

ELLIPSOID AND TEMPORAL KERNEL FITTING TO SPIKE-TRIGGERED DATA FROM CHICHILNISKY LAB

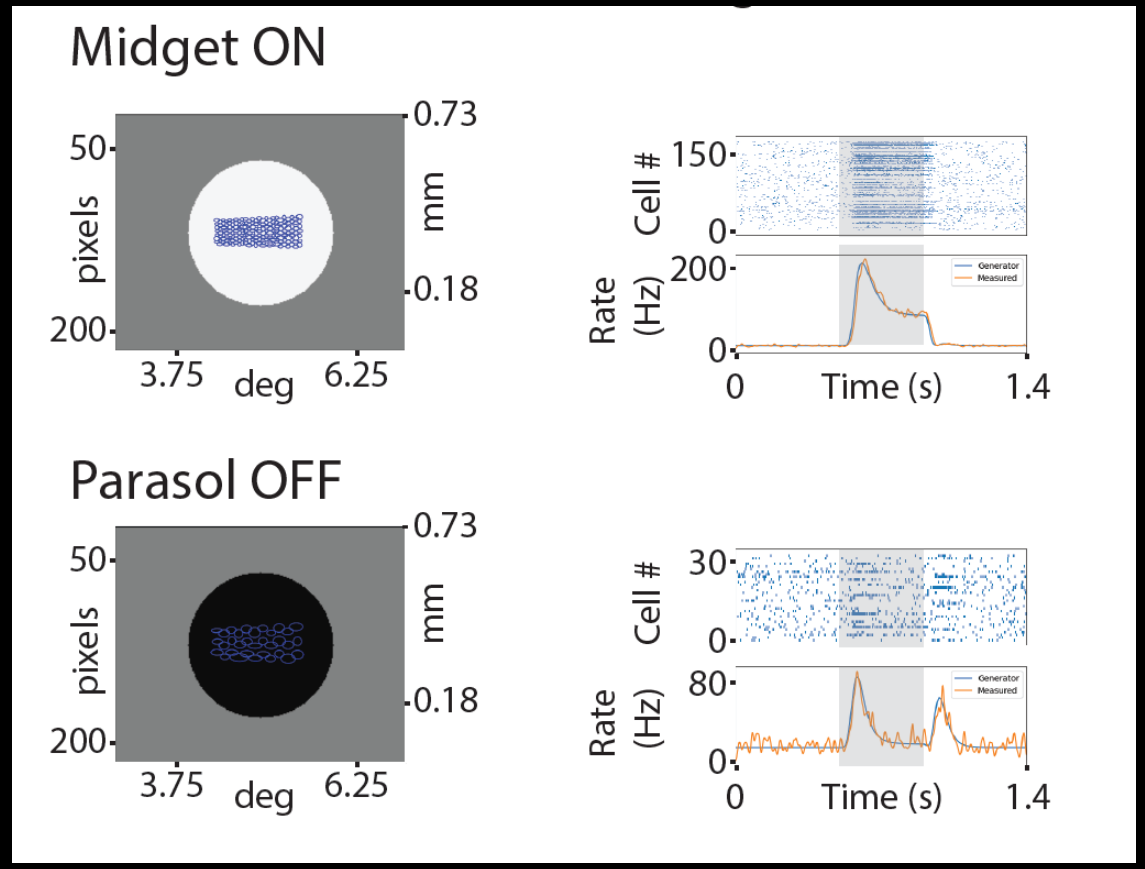


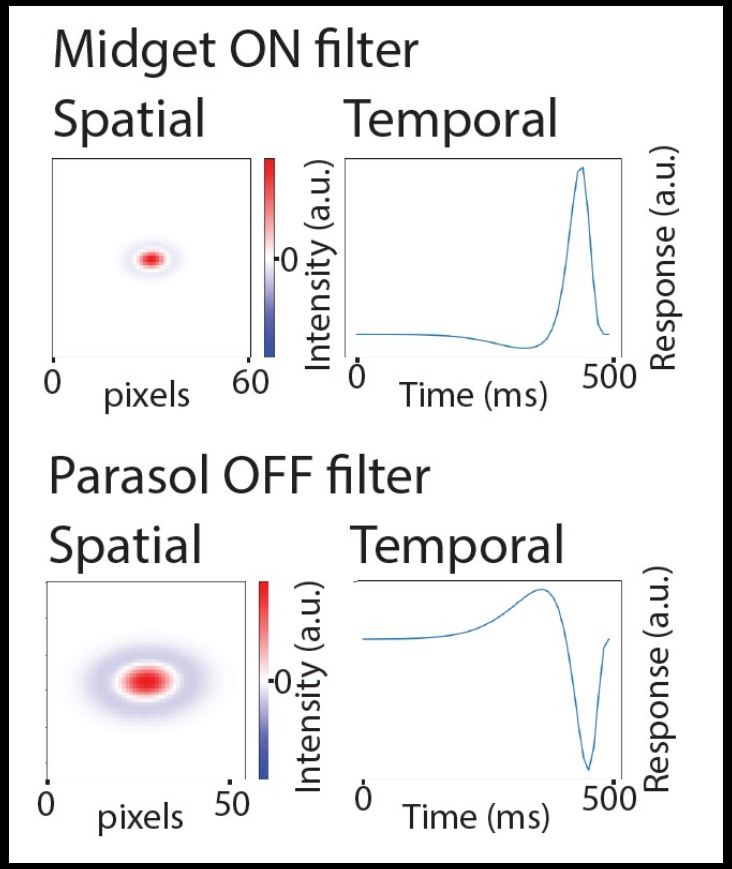


Hokkanen & Vanni, in preparation

FOUR GANGLION CELL (GC) TYPES

COVERS 96% OF FOVEAL AND 88% OF PERIPHERAL GC:S





Hokkanen & Vanni, in preparation

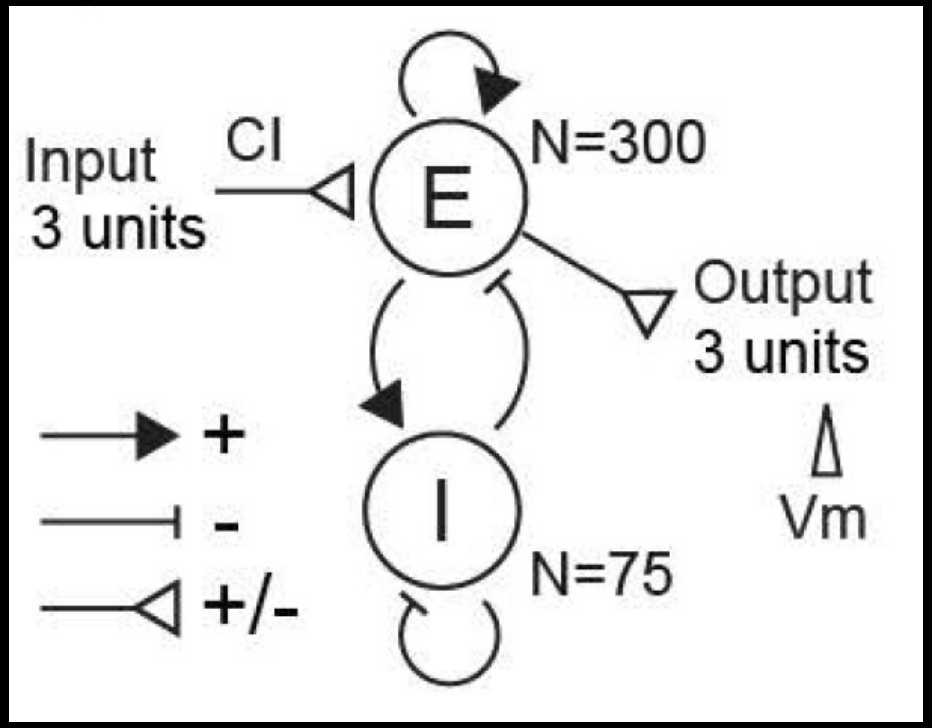
SELECTION OF INTERNAL MODEL USE LESS ENERGY THAN ACCURATE REPRESENTATION

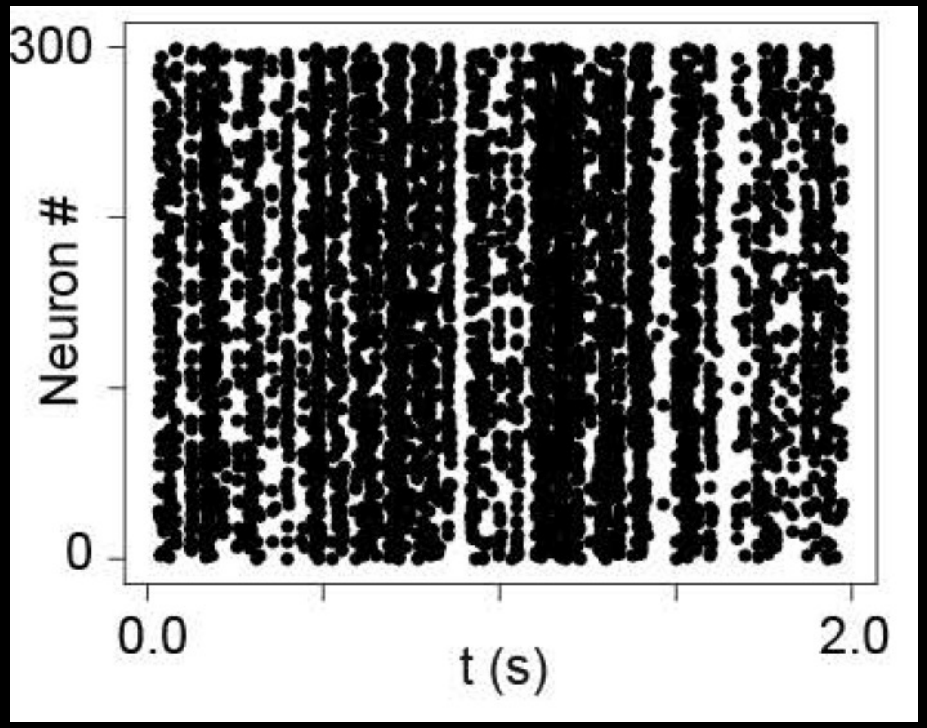
POSSIBLE ECOLOGICAL REASON FOR PREDICTIVE CODING

Artiñano et al., under review

SIMPLE SPIKING NETWORK MODEL

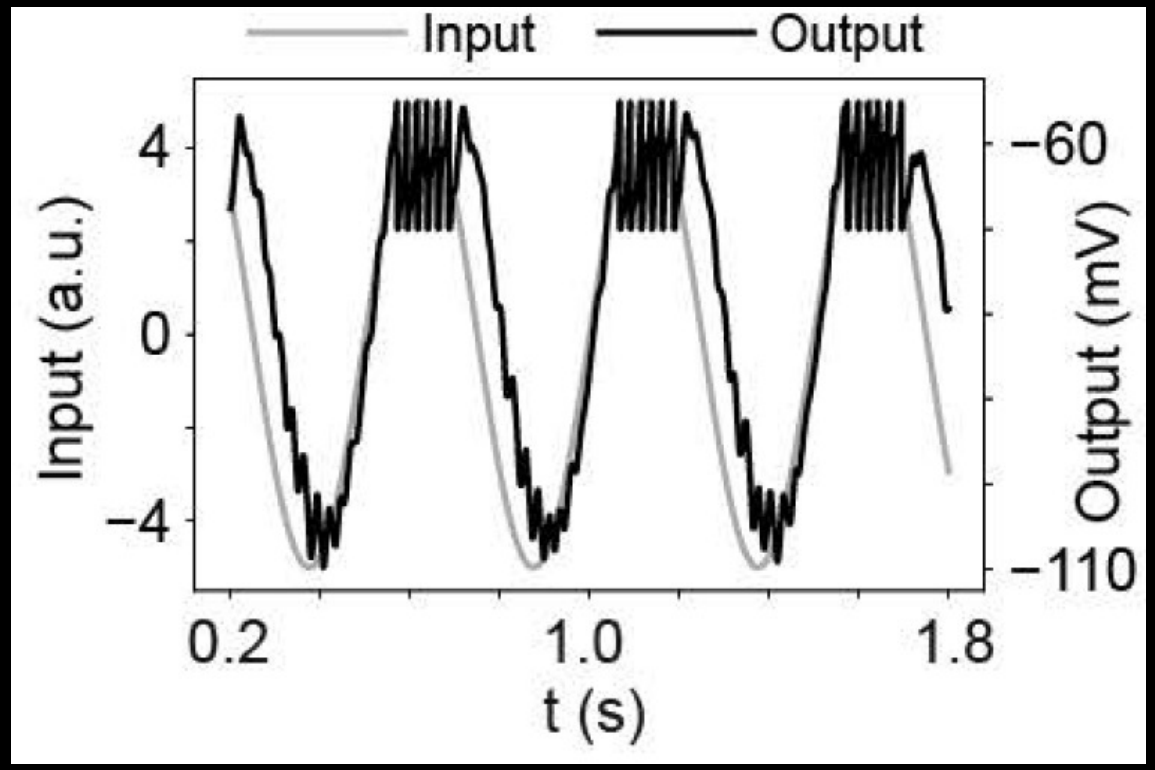
FOLLOWING BRENDEL ET AL PLOS COMPUT BIOL 2020





Artiñano et al., under review

NETWORK FIRST LEARNS TO REPLICATE THE 3 INPUT CHANNEL AMPLITUDES AT THE 3 OUTPUT UNIT MEMBRANE VOLTAGES

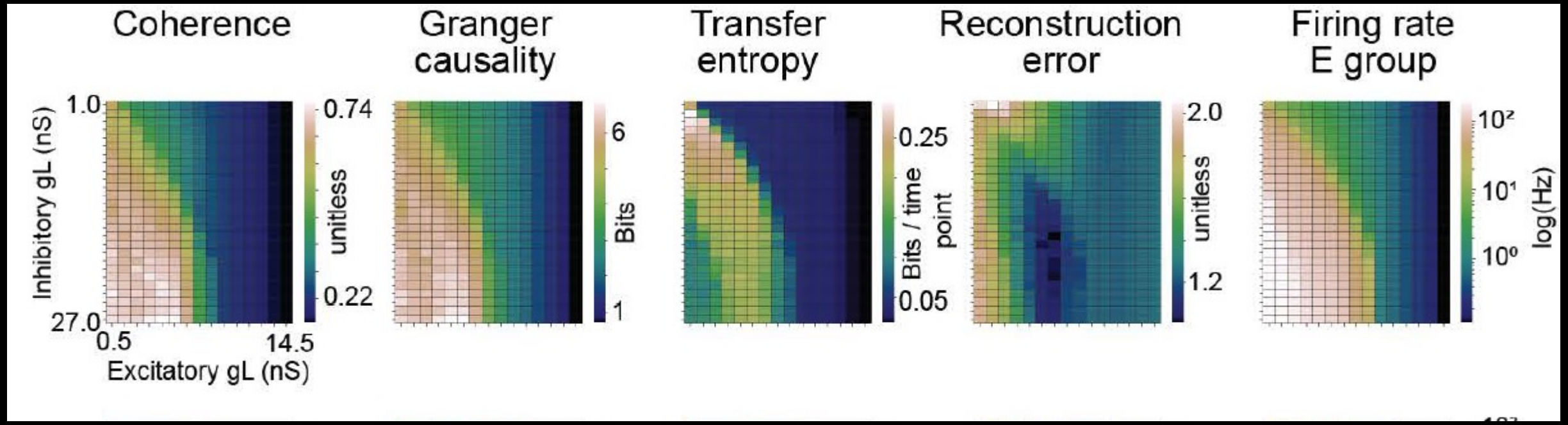


Artiñano et al., under review

HOW BIOPHYSICAL PARAMETER VARIATIONS AFFECT INFORMATION TRANSFER?

Artiñano et al., under review

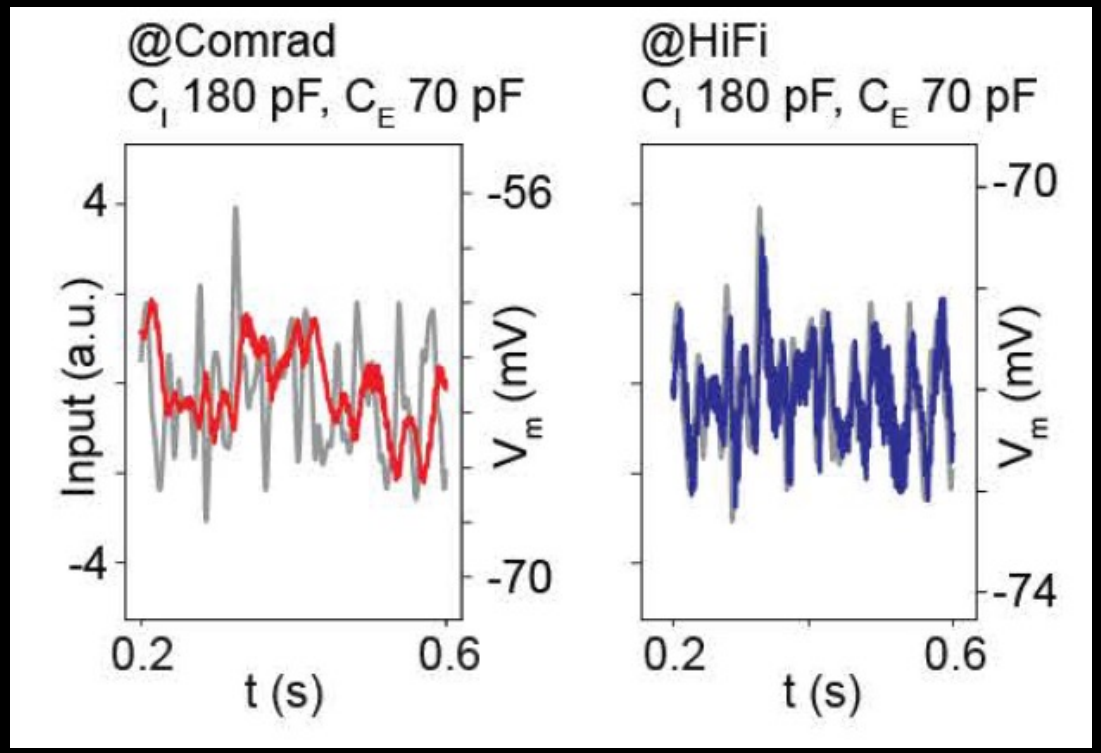
FOUR DISTINCT METRICS SHOW HIGHER INFORMATION TRANSFER WITH HIGHER FIRING RATE

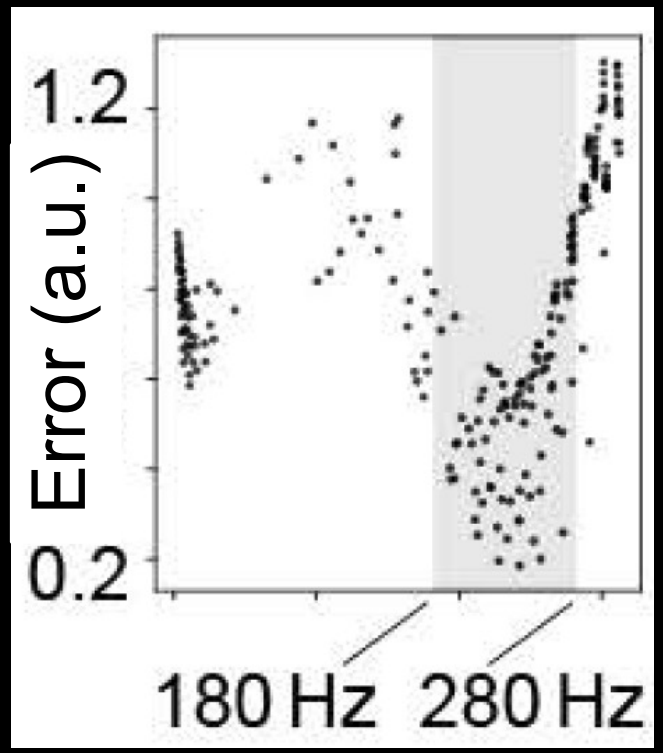


Artiñano et al., under review

ACCURATE REPRESENTION IS EXPENSIVE

ONLY SPECIAL PARAMETER COMBINATIONS, HIGH FIRING RATES, AND OUTPUT UNITS WITH SHORT MEMORY FOLLOW THE FAST INPUT TRANSIENTS

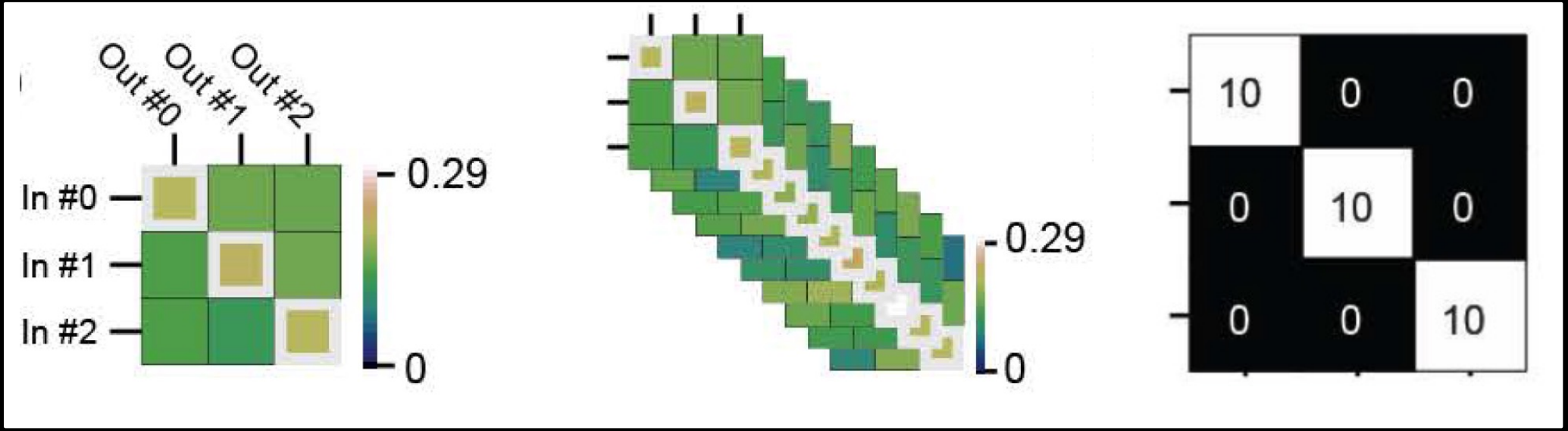




Artiñano et al., under review

INPUT => OUTPUT CLASSIFICATION ACCORDING TO TRANSMITTED INFORMATION

Coherence

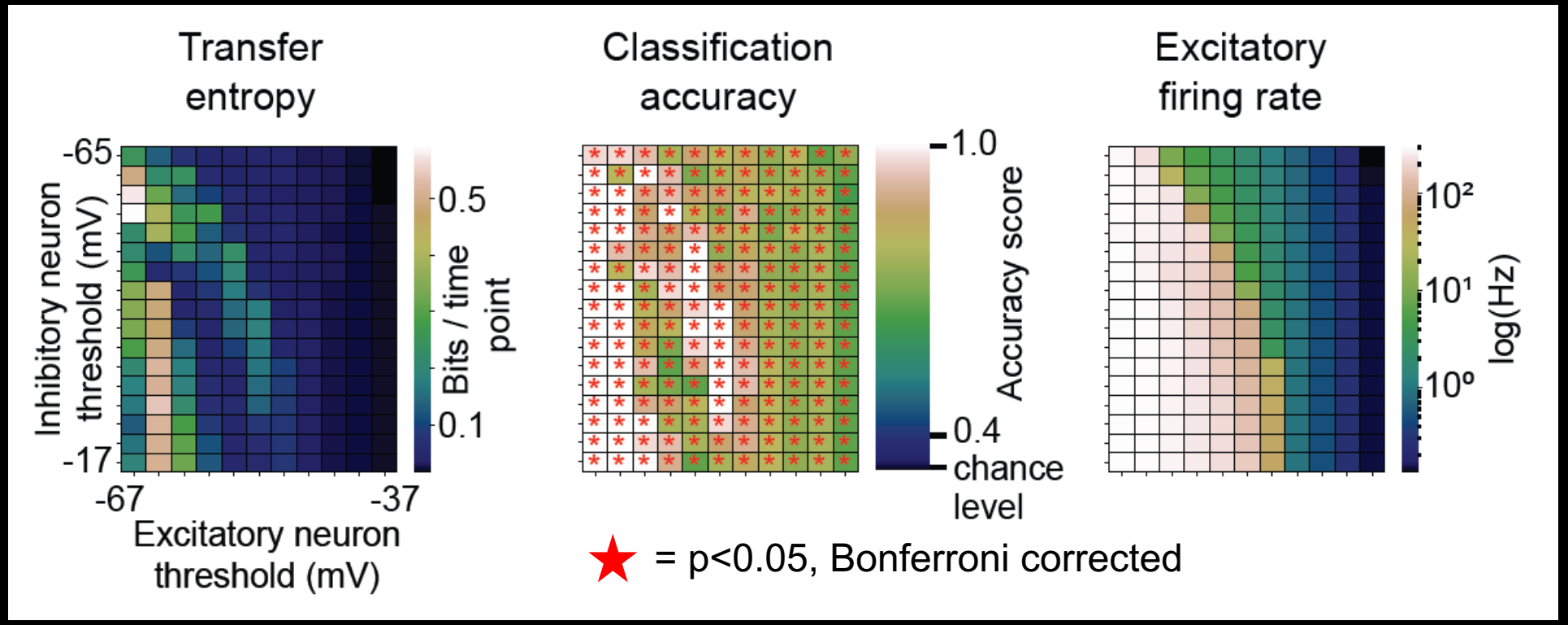


Input to output pairing

10 replications for 30 pairs

Confusion matrix

CLASSIFICATION SURVIVES VERY LOW FIRING RATES

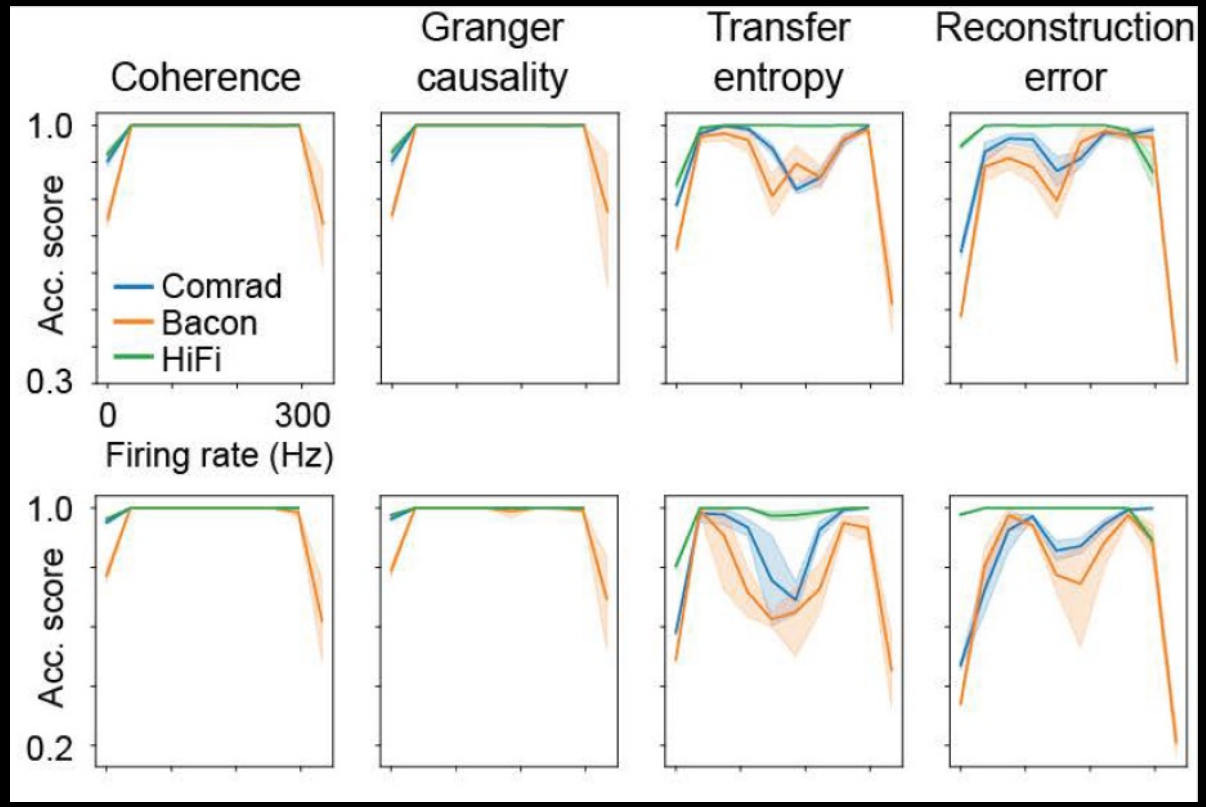


Artiñano et al., under review

ACCURACY SCORES DIP WHEN CELLS EITHER CEASE FIRING OR SATURATE

3 by 3

6 by 6



Artiñano et al., under review

IF TRANSMITTED INFORMATION CAN BE TURNED INTO MODEL SELECTION, ACTIVATING AN INTERNAL MODEL WOULD BE AN ECONOMICAL WAY OF REPRESENTING THE ENVIRONMENT

Artiñano et al., under review

ACKNOWLEDGEMENTS

- Vafa Andalibi ..... Programming Cxsystem
- Alessandra Angelucci ..... Neuroinformatics
- Tomás Garnier Artiñano ..... Simulations for infometrics
- Iiris Atula ..... Math for infometrics
- Margaux Calice ..... Thalamocortical system
- Hanna Heikkinen ..... Program preceding CxSystem
- Henri Hokkanen ..... Retina, modeling, programming, neuroinformatics
- Matteo Maestri ..... Control simulations for infometrics
- Francesca Werner ..... Digitazing data for neuroinformatics

TEMPLATE

- 1) What was the scientific question?
  - Biologically and computationally meaningful models of macaque monkey visual cortical areas V1, V2 and V5
- 2) How did you/project partners address it?
  - Neuroinformatics, High-level tool dev, simulations, information metrics
- 3) What are the main outcomes of the project?
  - Publications, GitHub repo
- 4) What are the next steps of the project?
  - After retina model, work towards V1 model using Grossberg ART model as a scaffold