
HAPPY
SATURDAY
FROM
UC BERKELEY

THE NEUROPHYSIOLOGY OF

CLASSICAL COMPUTATION

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A PLEA FOR

STRUCTURED PROBABILISTIC MODELS

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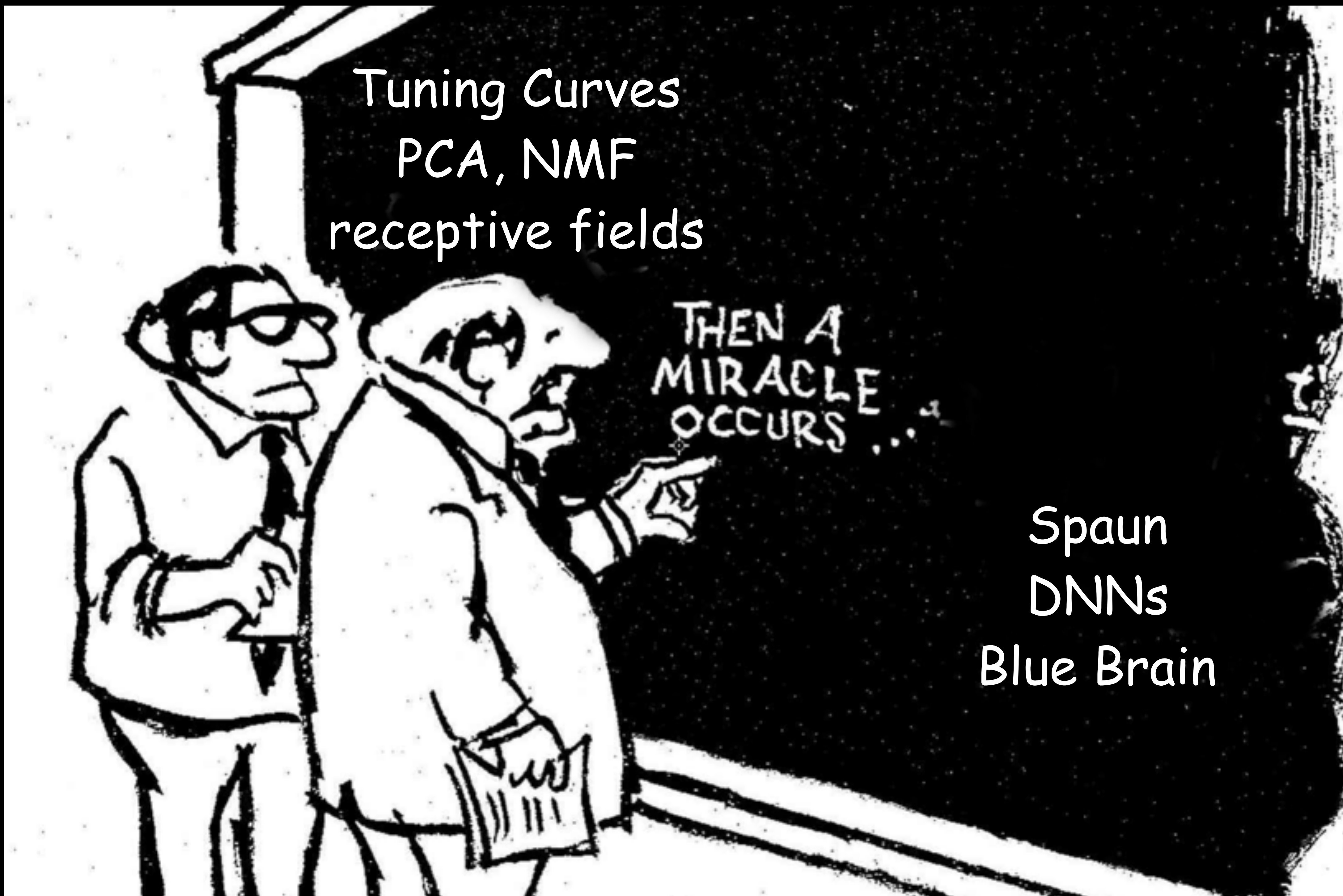
IS THIS OUR PLAN?



STOP REDUCING DIMENSIONS

- What would it tell us about a processor?
- Where do we go from there?
- A plea for model-driven data analysis

1.1 A Material Culture of the Laboratory

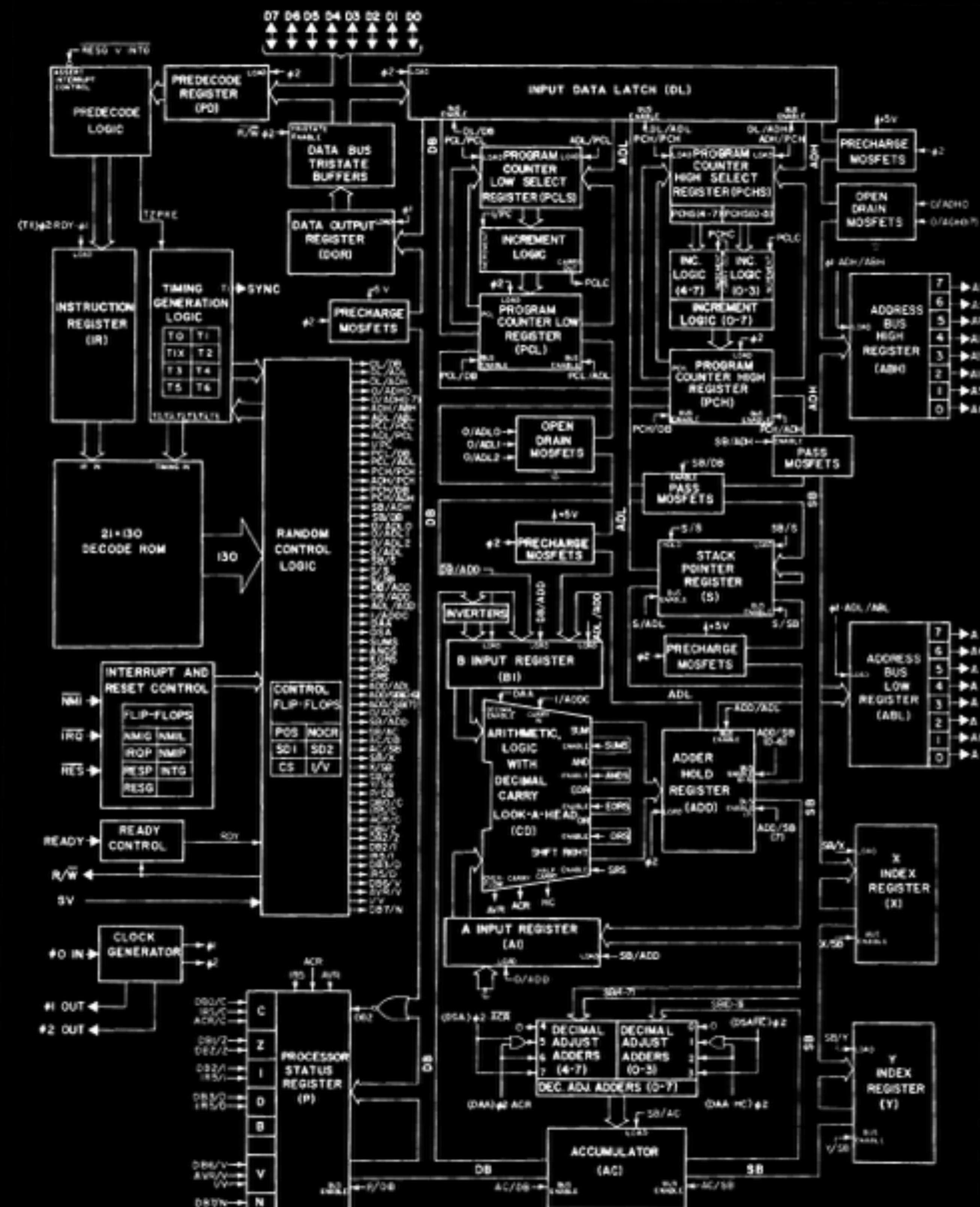
In 1964, some of the world's leading experimental physicists gathered in Karlsruhe, West Germany, to discuss the radical changes then underway in their profession. Where an earlier generation of experimenters saw the design, construction, and use of apparatus as defining features of their identity, now much of this activity was permanently out of the physicists' hands. Where physicists once collated data in notebooks and analyzed them with slide rules, the computer had now taken over much of this work—storing, processing, even analyzing information and delivering it in publishable graphic form. Huge teams of physicists clustered around barn-sized bubble chambers at centralized accelerators. Throughout the laboratory, the relations among computer programmers, experimenters, instrument makers, and engineers were utterly in flux. In a taped discussion from the Karlsruhe conference, Lew Kowarski, an influential physicist from the major European particle accelerator, CERN, waxed enthusiastic about these changes, extolling the virtues of assembling millions of pictures and tackling them with automatic techniques. The audience was stunned. One physicist, obviously pained, asked about the danger present in automation: mightn't it squelch innovation? Another confessed how "frightened" he was to hear that "in a few years . . . one would not go to start a new experiment but one would just go into the archives, get a few magnetic tapes[,] and start to scan the tapes from a new point of view[—]that would be the experiment." Knowledge from archives—what could be worse?

PETER GALISON. IMAGE AND LOGIC: A MATERIAL CULTURE OF MICROPHYSICS. 1997.

TEXAS INSTRUMENTS
TTL Logic
Standard TTL, Schottky,
Low-Power Schottky
Data Book
Data Book
TTL Logic
Standard TTL, Schottky,
Low-Power Schottky
1988
1988
TEXAS INSTRUMENTS
Data Book
TTL Logic
Standard TTL, Schottky,
Low-Power Schottky
1988

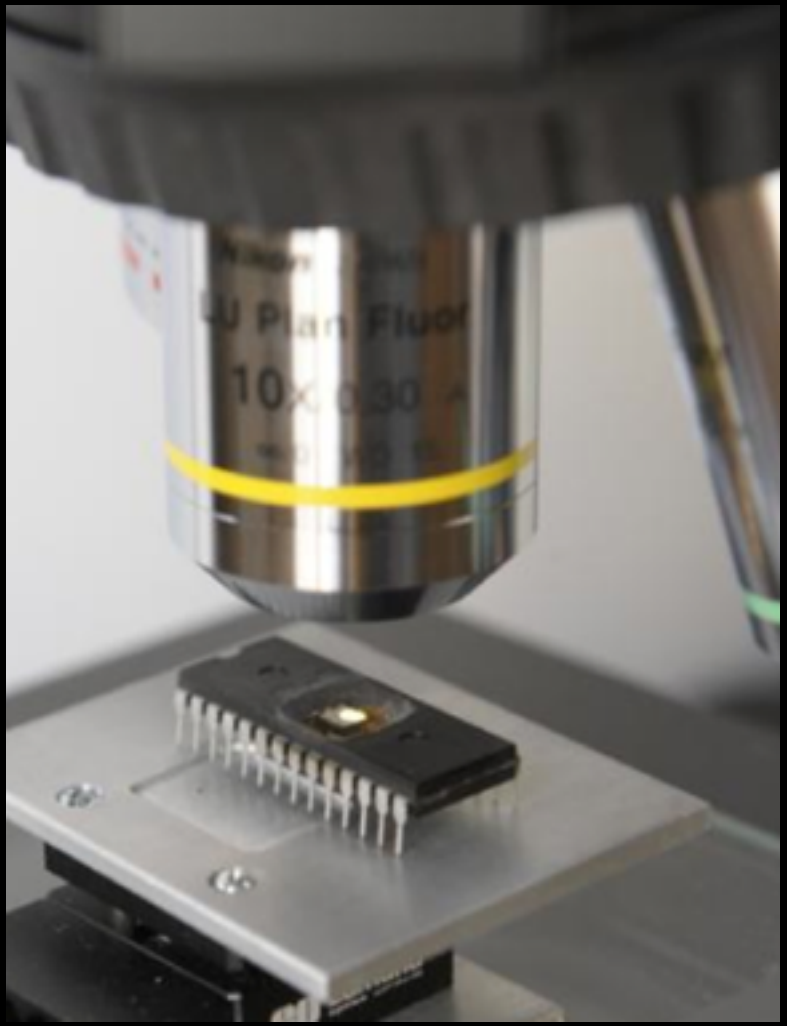
OUR MODEL ORGANISM - MOS6502

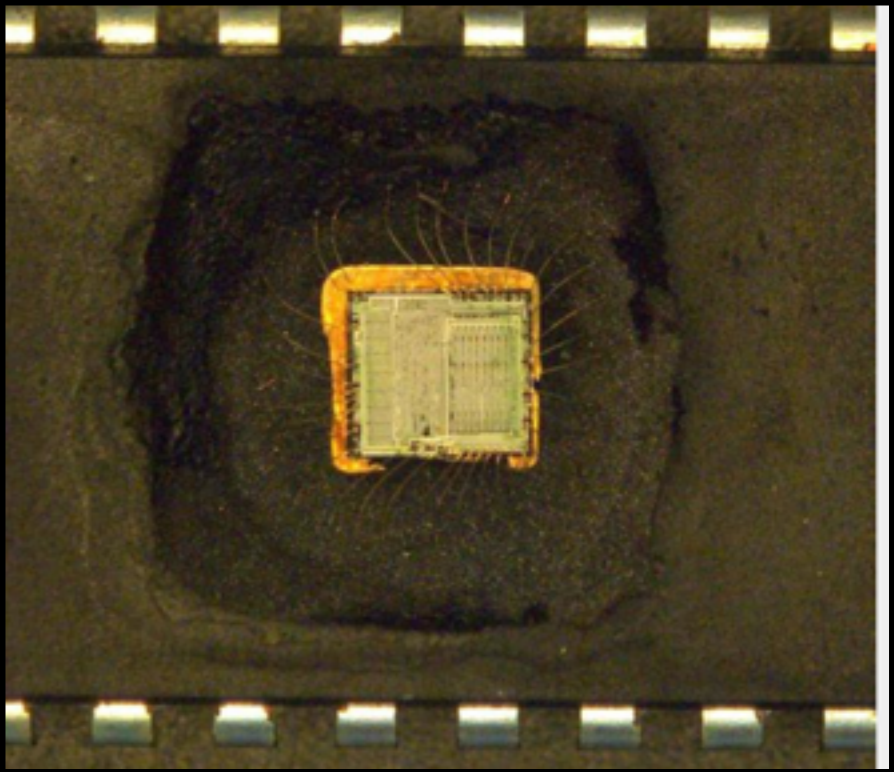
- 3510 transistors,
- designed by hand, 1975
- Atari, Apple 1 &2



CONNECTOMIC RECONSTRUCTION

WELL, SOME OTHER PEOPLE DID CONNECTOMICS...

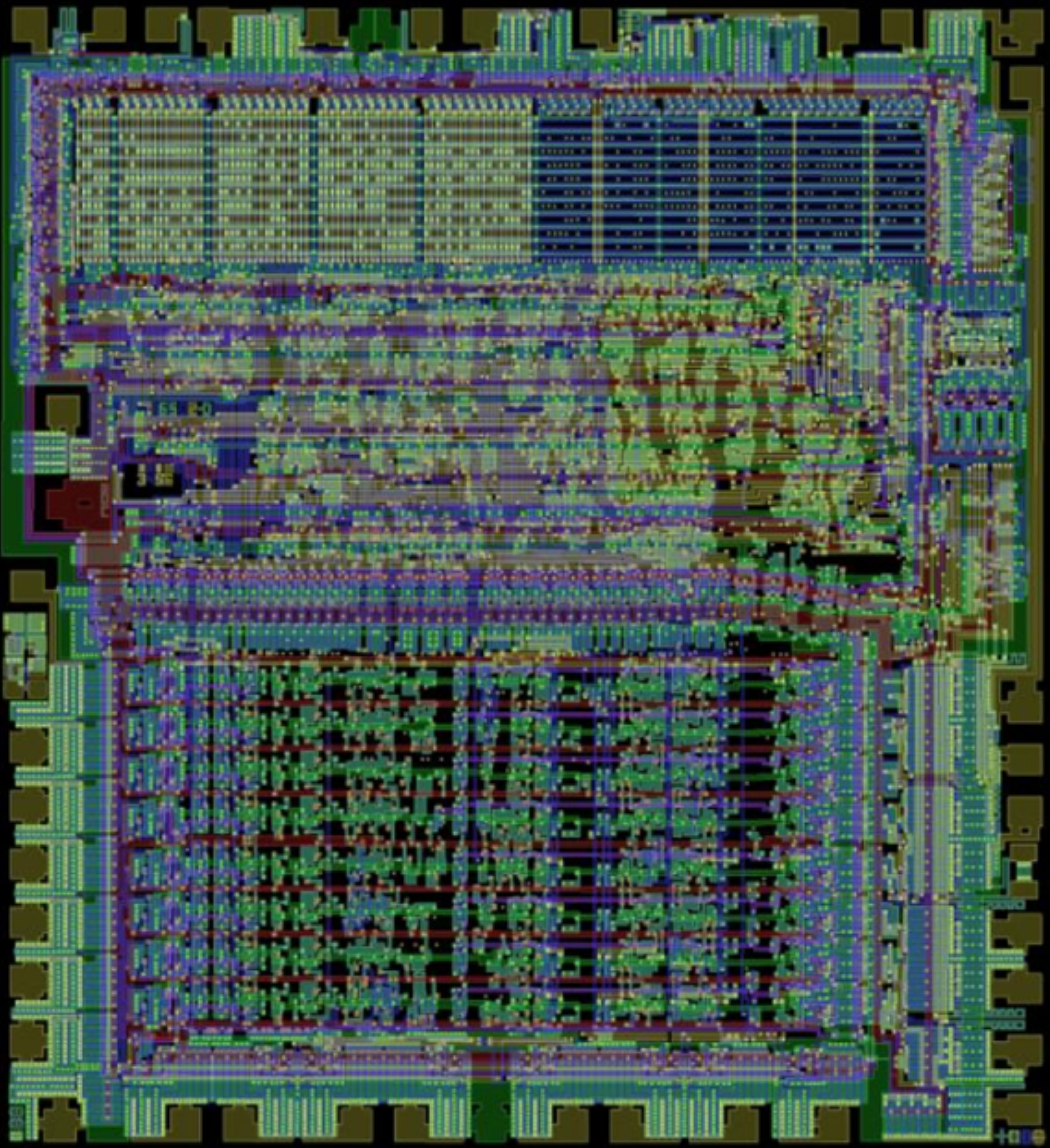




VISUALIZING A CLASSIC CPU IN ACTION, SIGGRAPH 2010
HTTP://VISUAL6502.ORG/DOCS/6502_IN_ACTION_14_WEB.PDF

HTTP://VISUAL6502.ORG

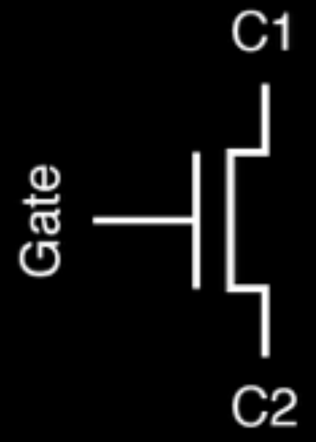
THE RESULT



"Simulation, not emulation"

Every wire, every transistor

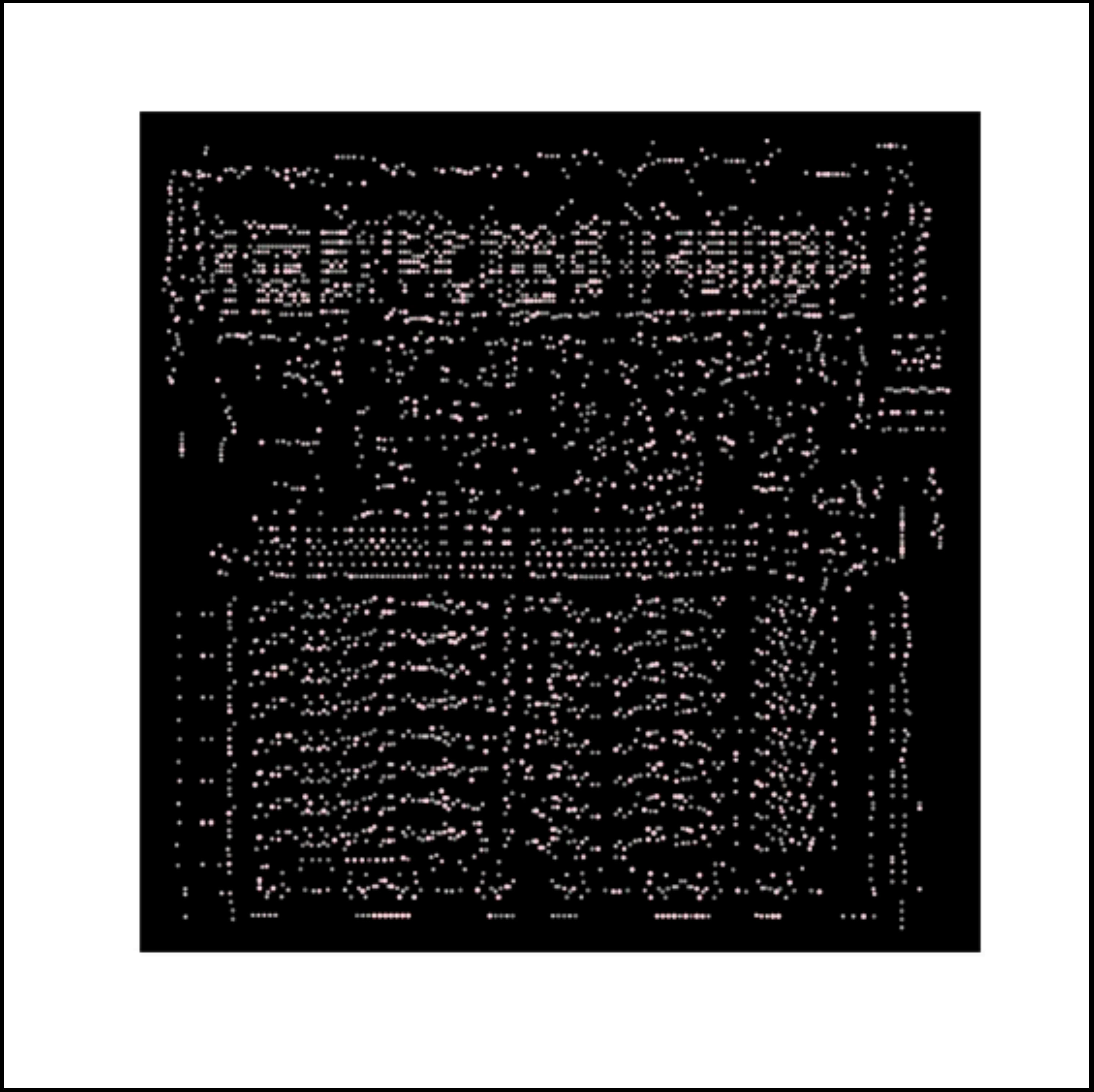
"Big Data" 500 MB/sec



[HTTP://VISUAL6502.ORG](http://visual6502.org)

AND IT WORKS!

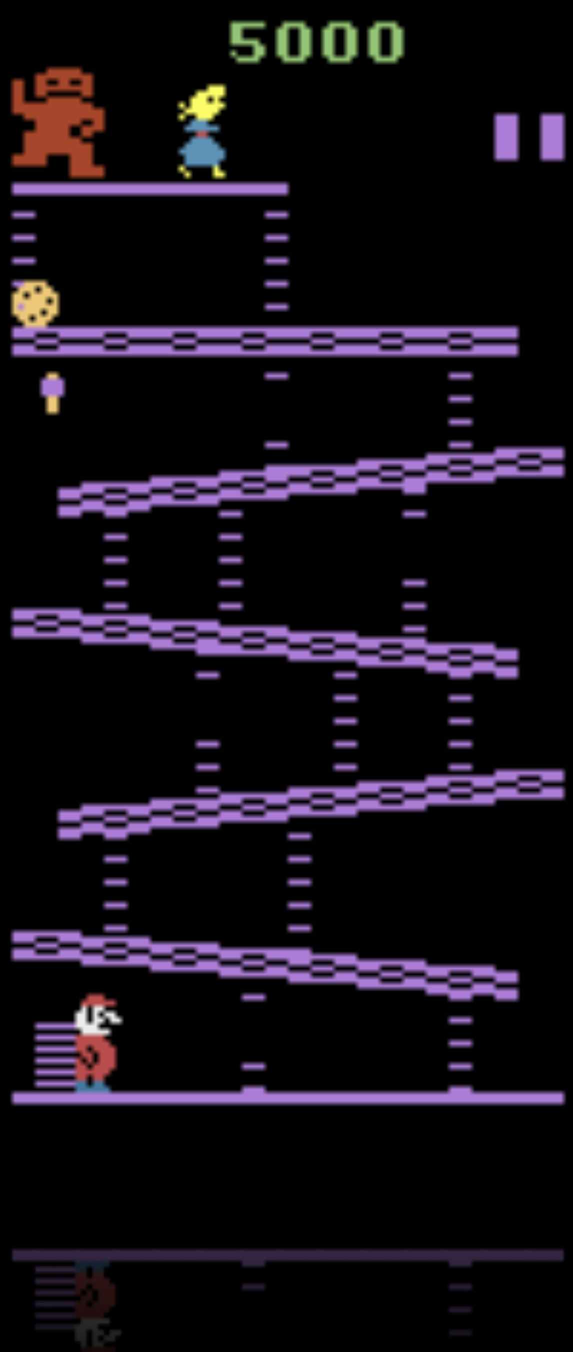
AND THE WHOLE TIME SERIES



WHAT ARE OUR TOOLS

- Behavior
- Connectomics
- Genetics (knock-out, knock-in, Cre-LOXP), etc.
- Ephys — single unit, multiunit,
- microscopy & imaging
- fMRI

BEHAVIORAL ASSAYS

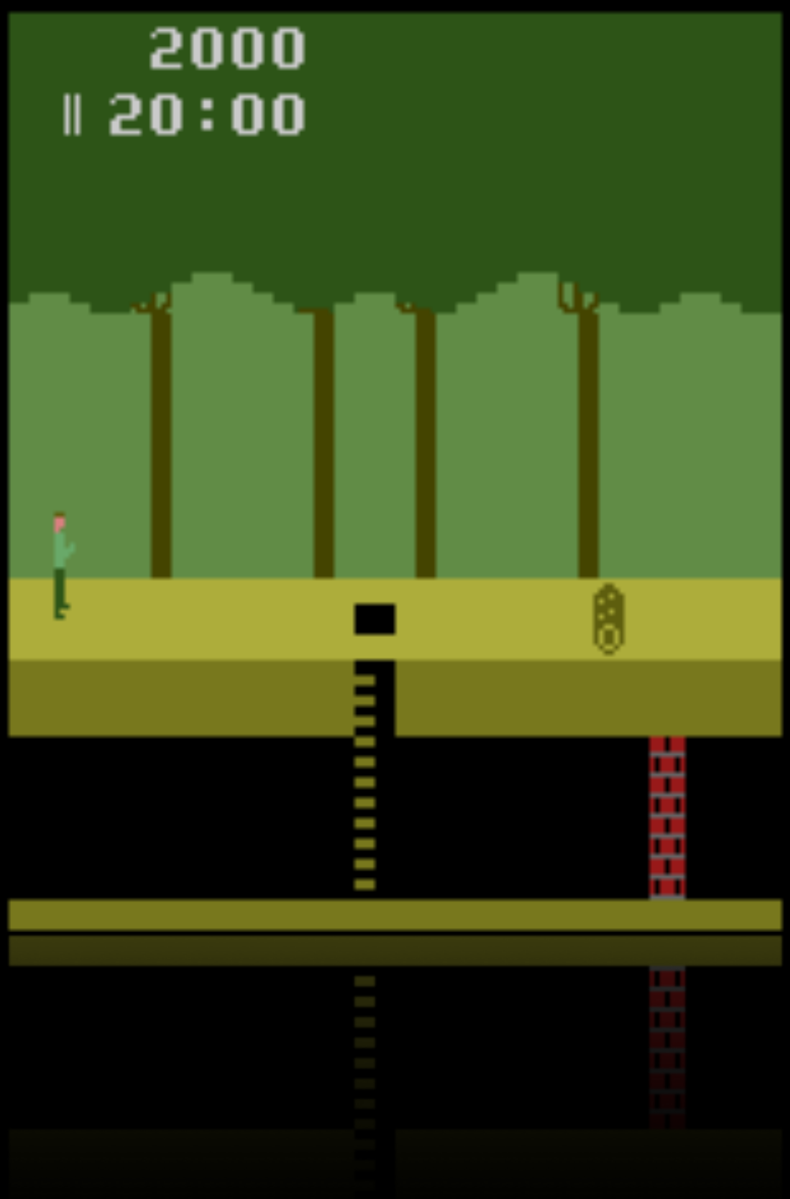


Donkey Kong

1981

Space Invaders

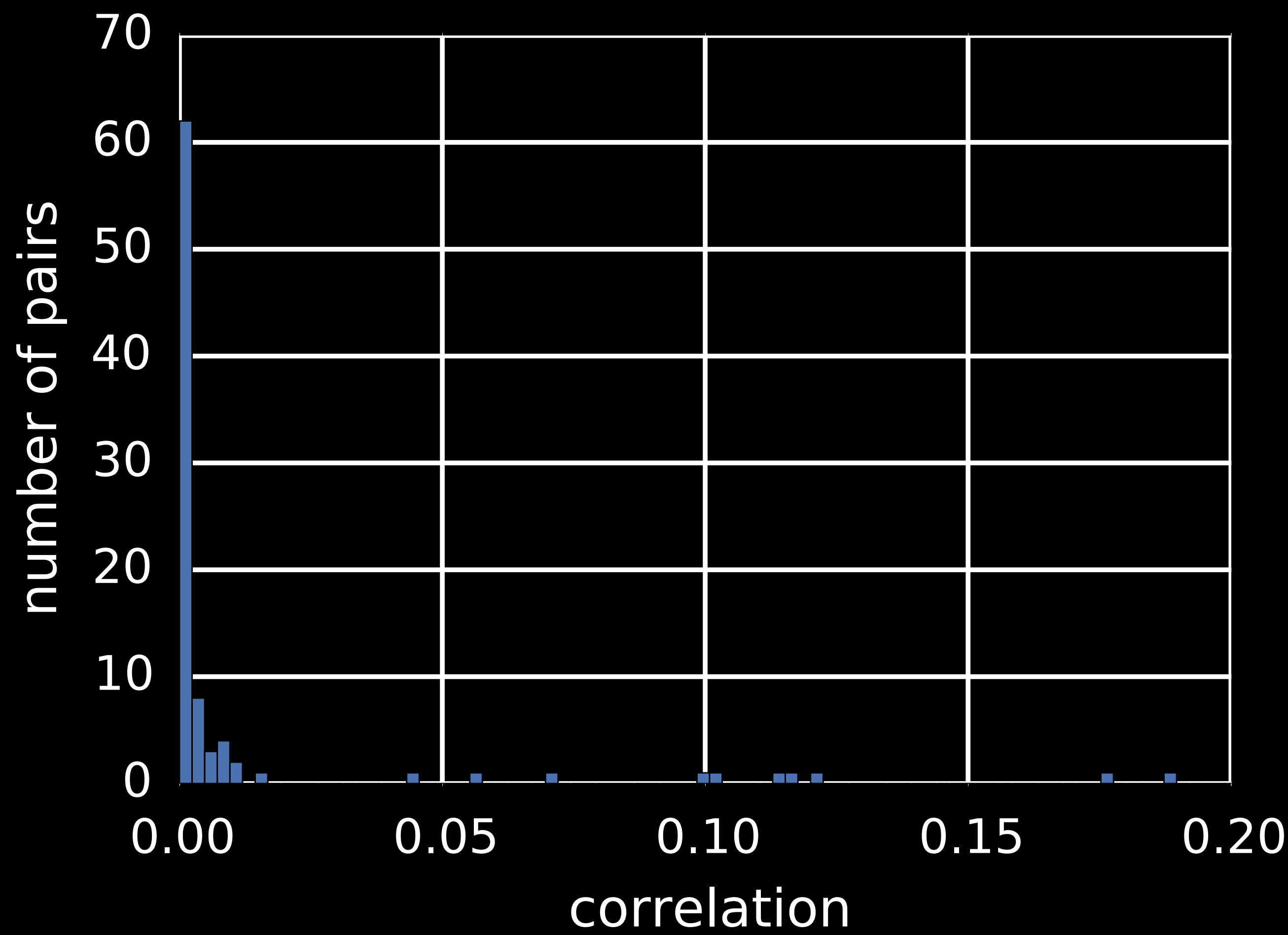
1978

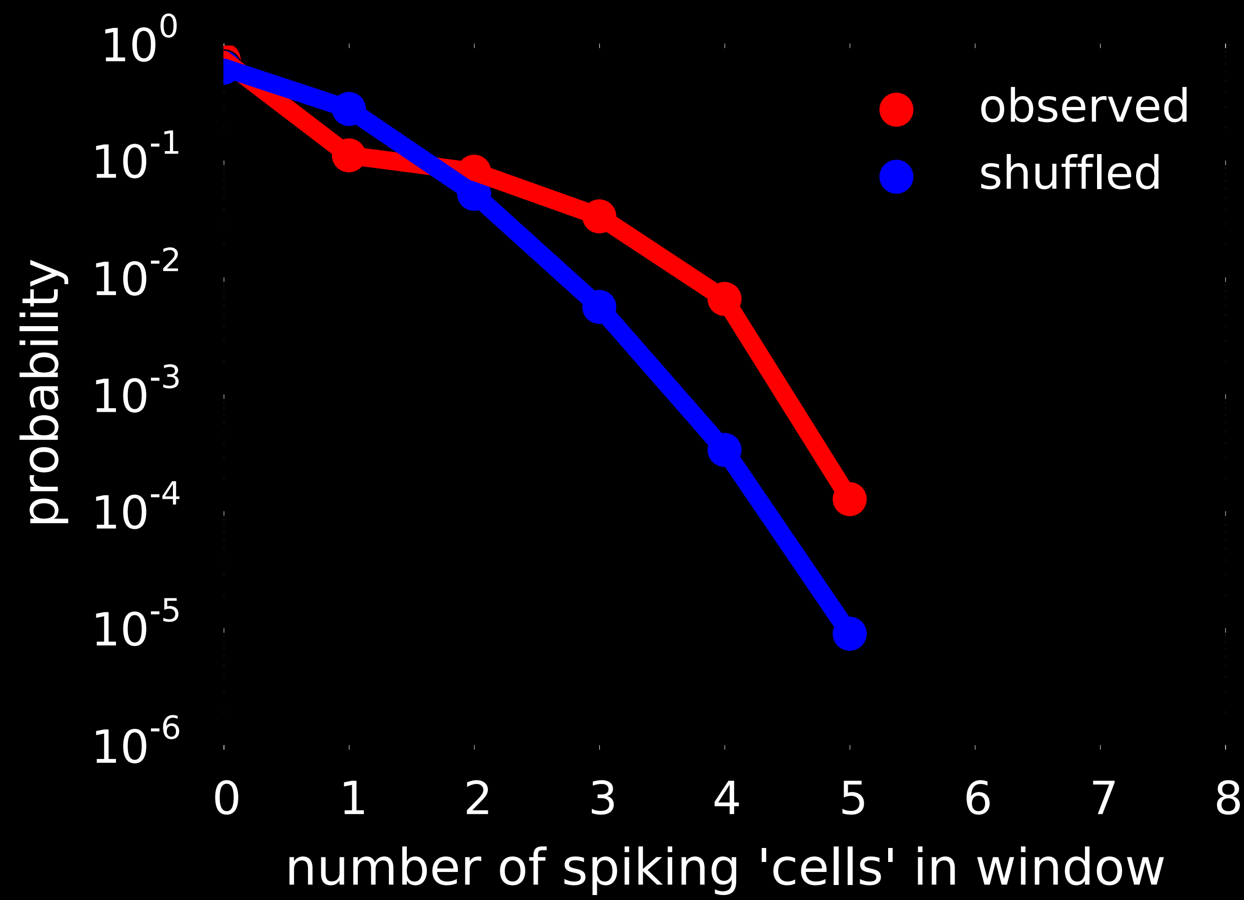


Pitfall

1981

SPIKE WORD ANALYSIS

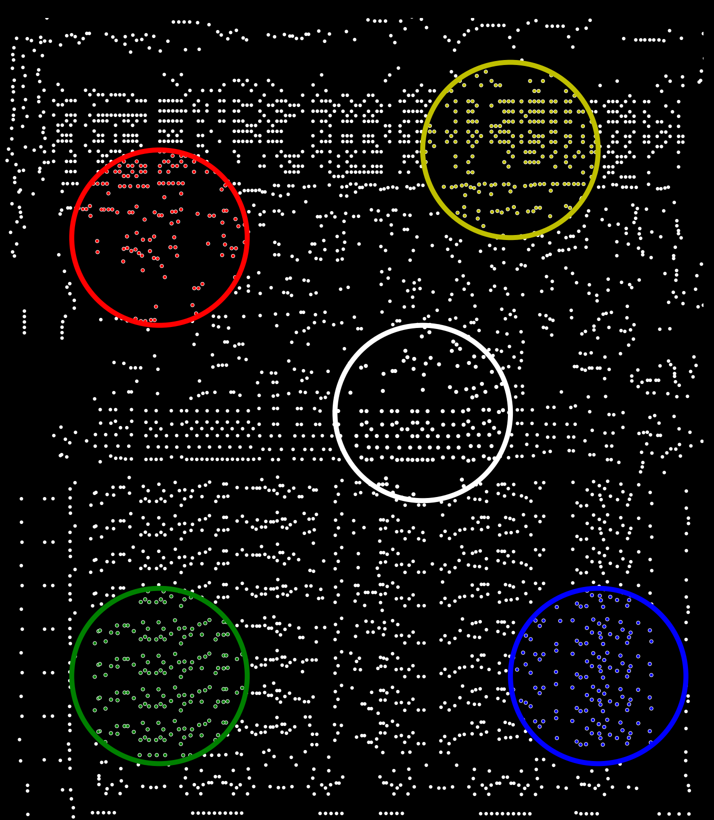




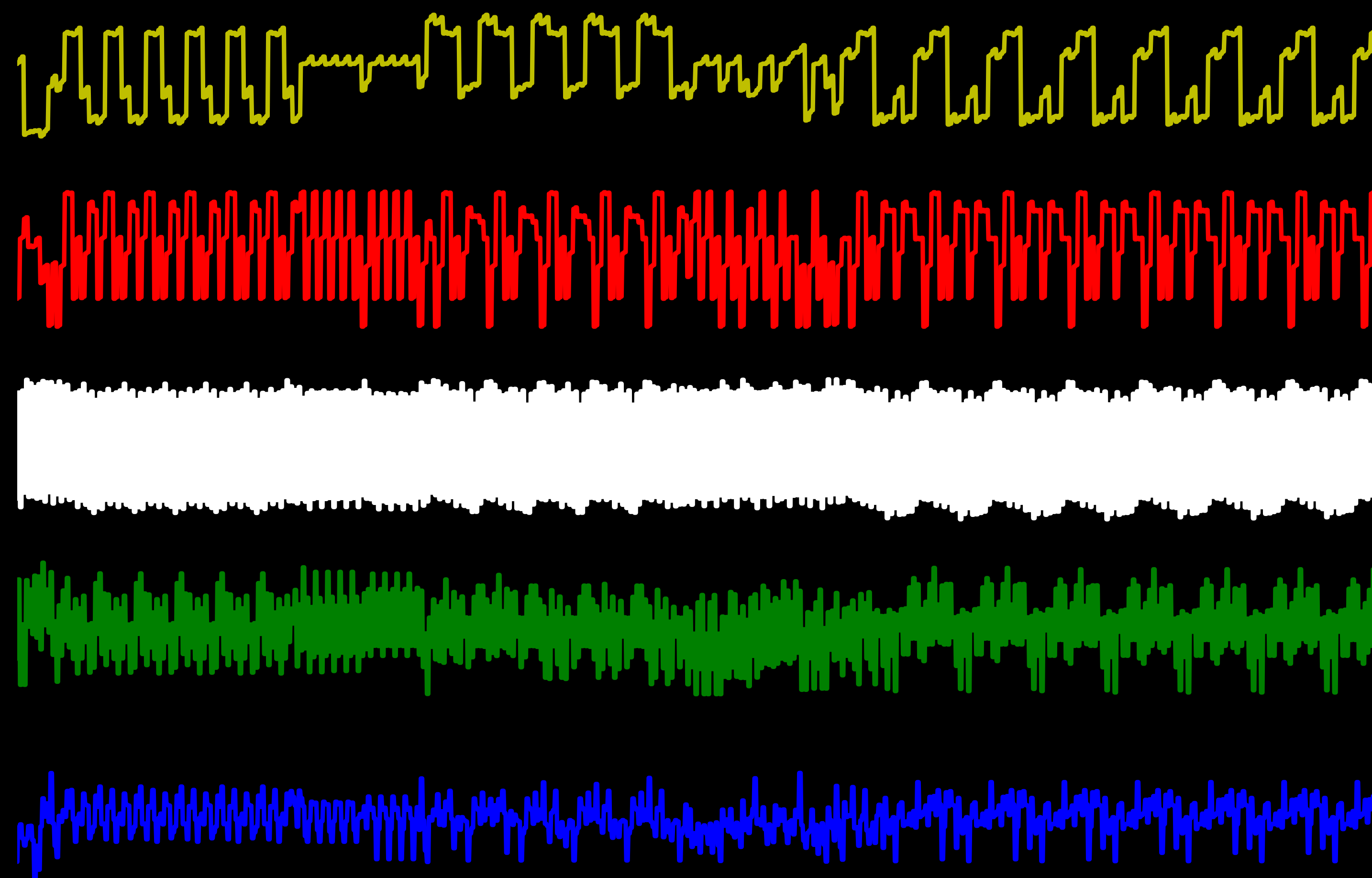
Very weak pairwise correlation but…

Schneidman, E., Berry, M. J., Segev, R., & Bialek, W. (2006). Weak pairwise correlations imply strongly correlated network states in a neural population. Nature, 440(April), 1007–1012. doi:10.1038/nature04701

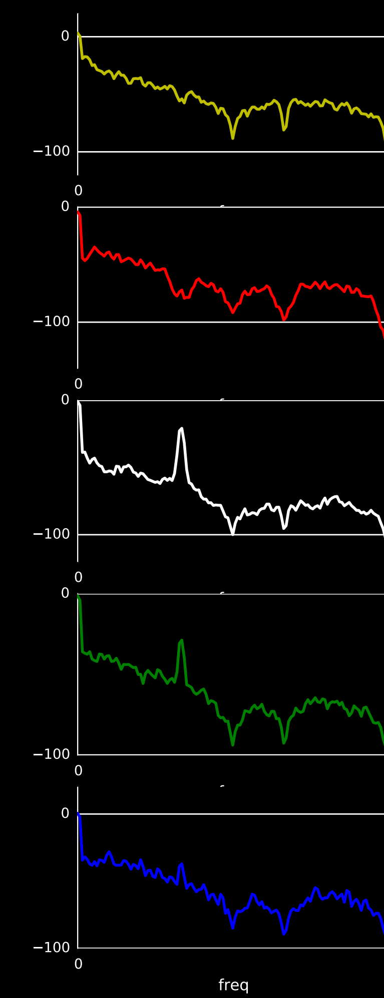
LOCAL FIELD POTENTIALS



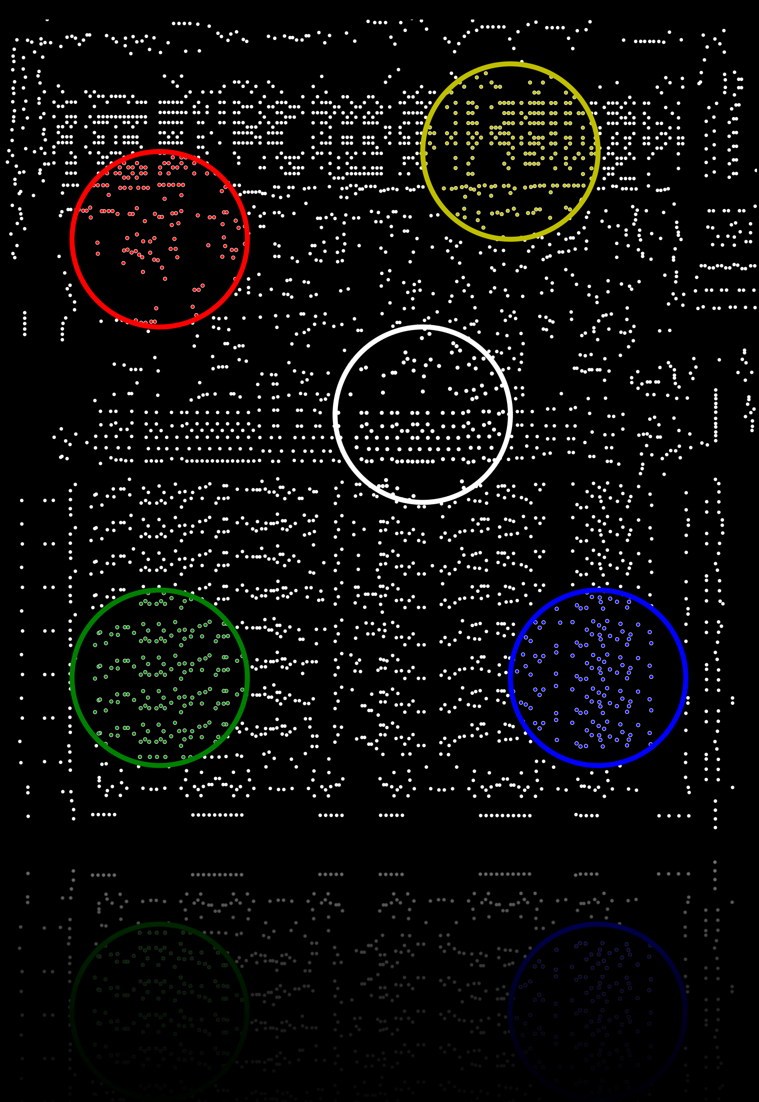
PROBE REGIONS

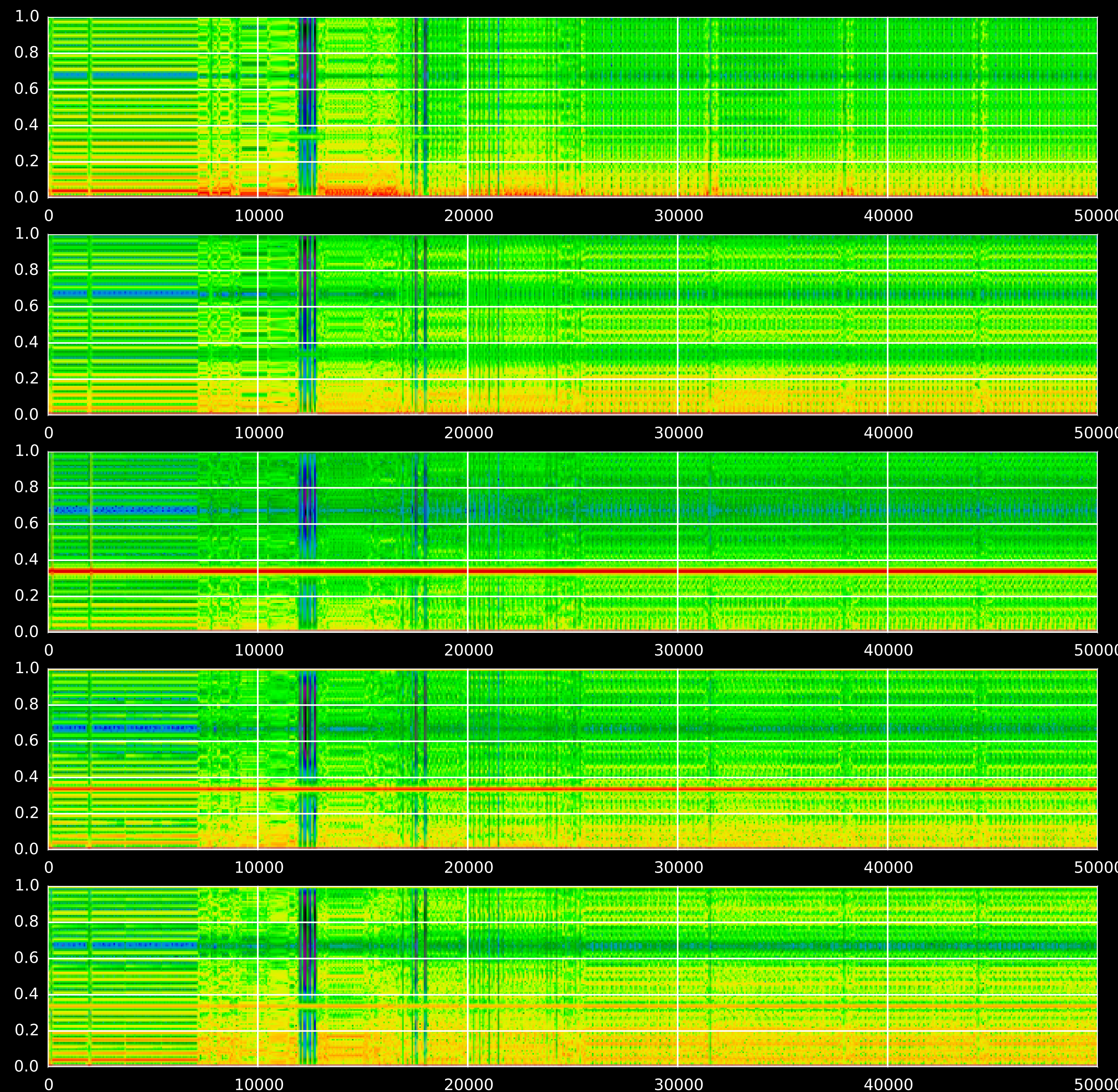


LOCAL CURRENT DENSITY



PSD





1.0
0.8
0.6
0.4
0.2
0.0
0
10000
20000
30000
40000
50000
1.0
0.8
0.6
0.4
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0.0
0
10000
20000
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40000
50000
1.0
0.8
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0.4
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10000
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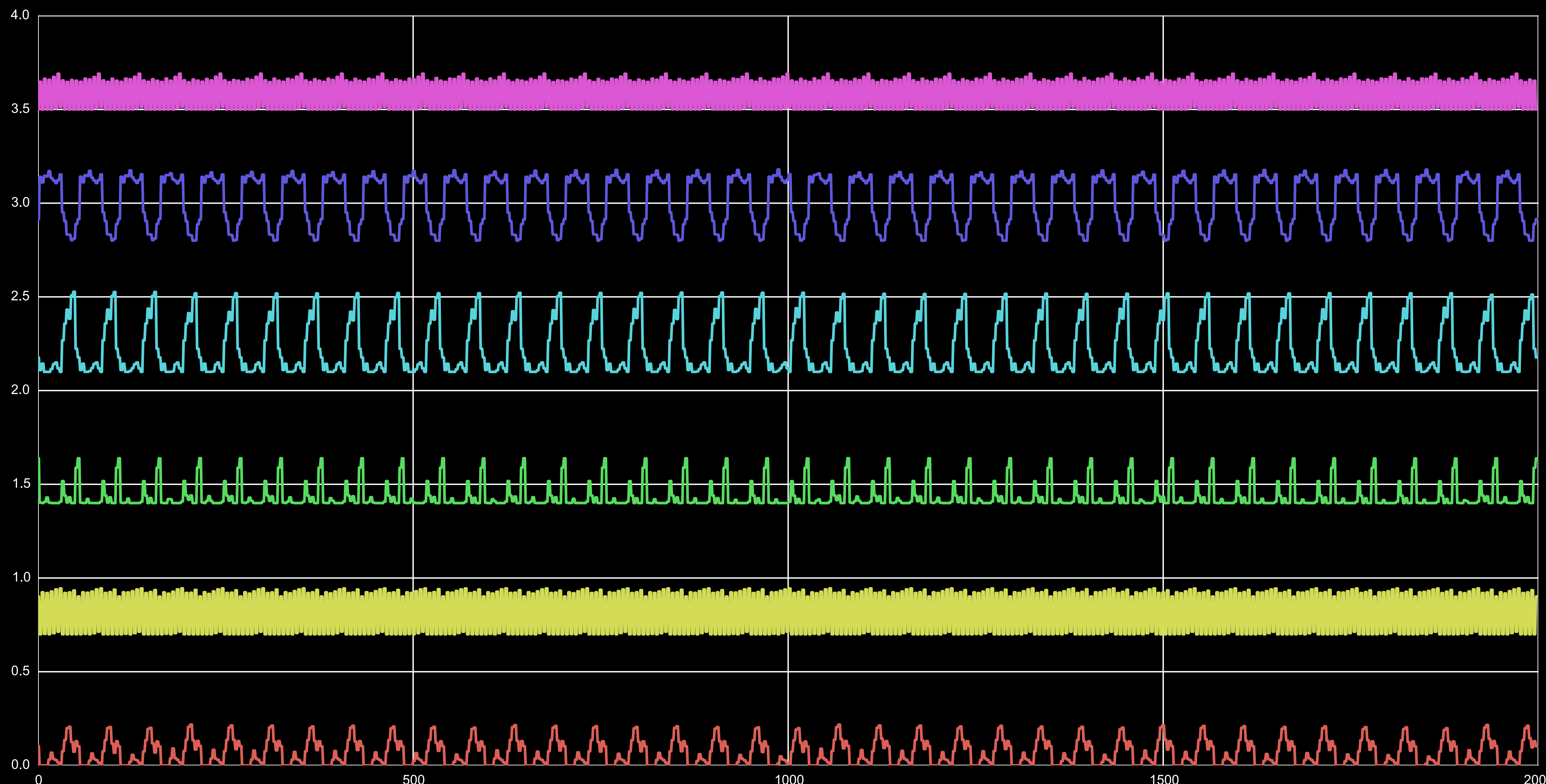
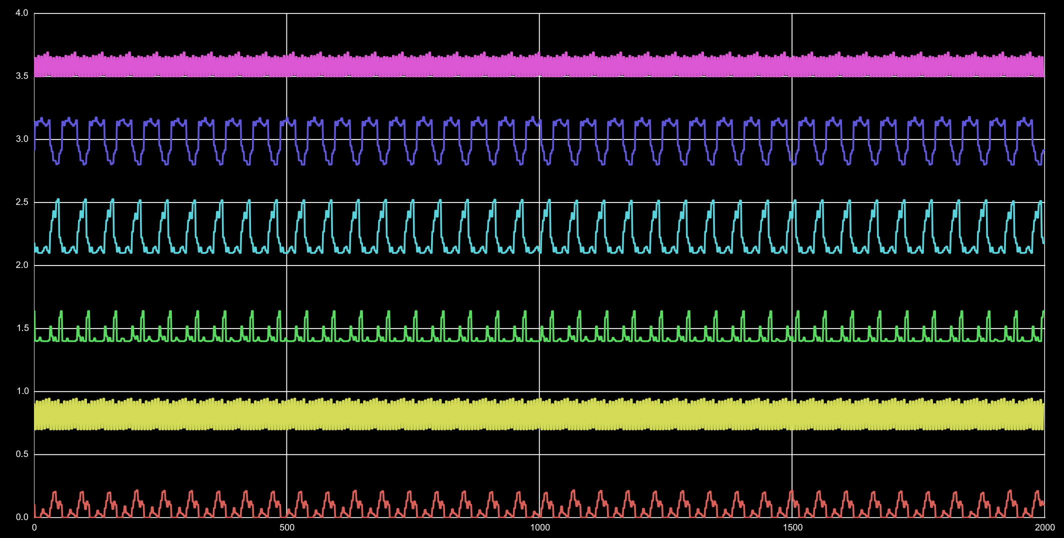
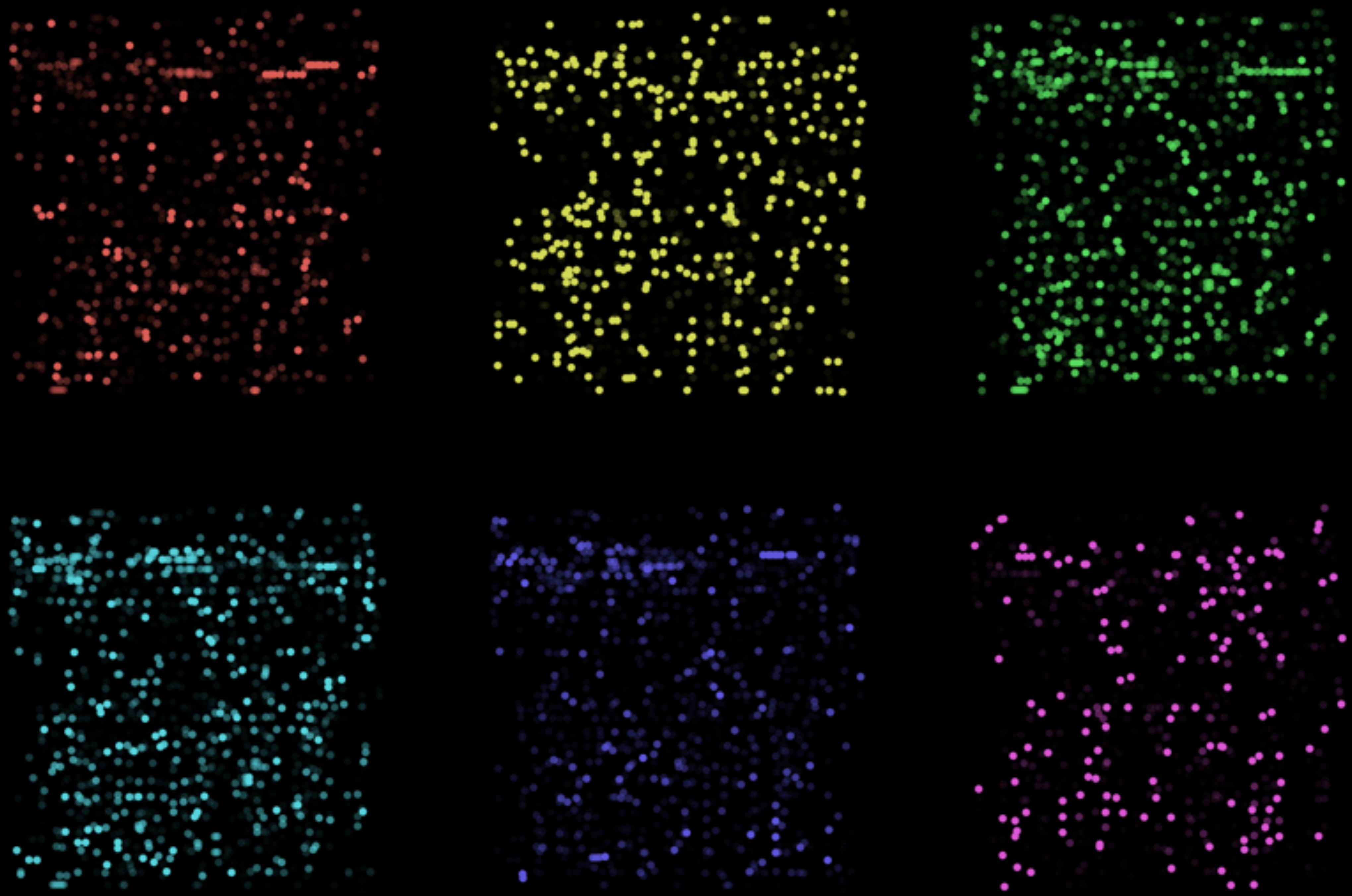
50000

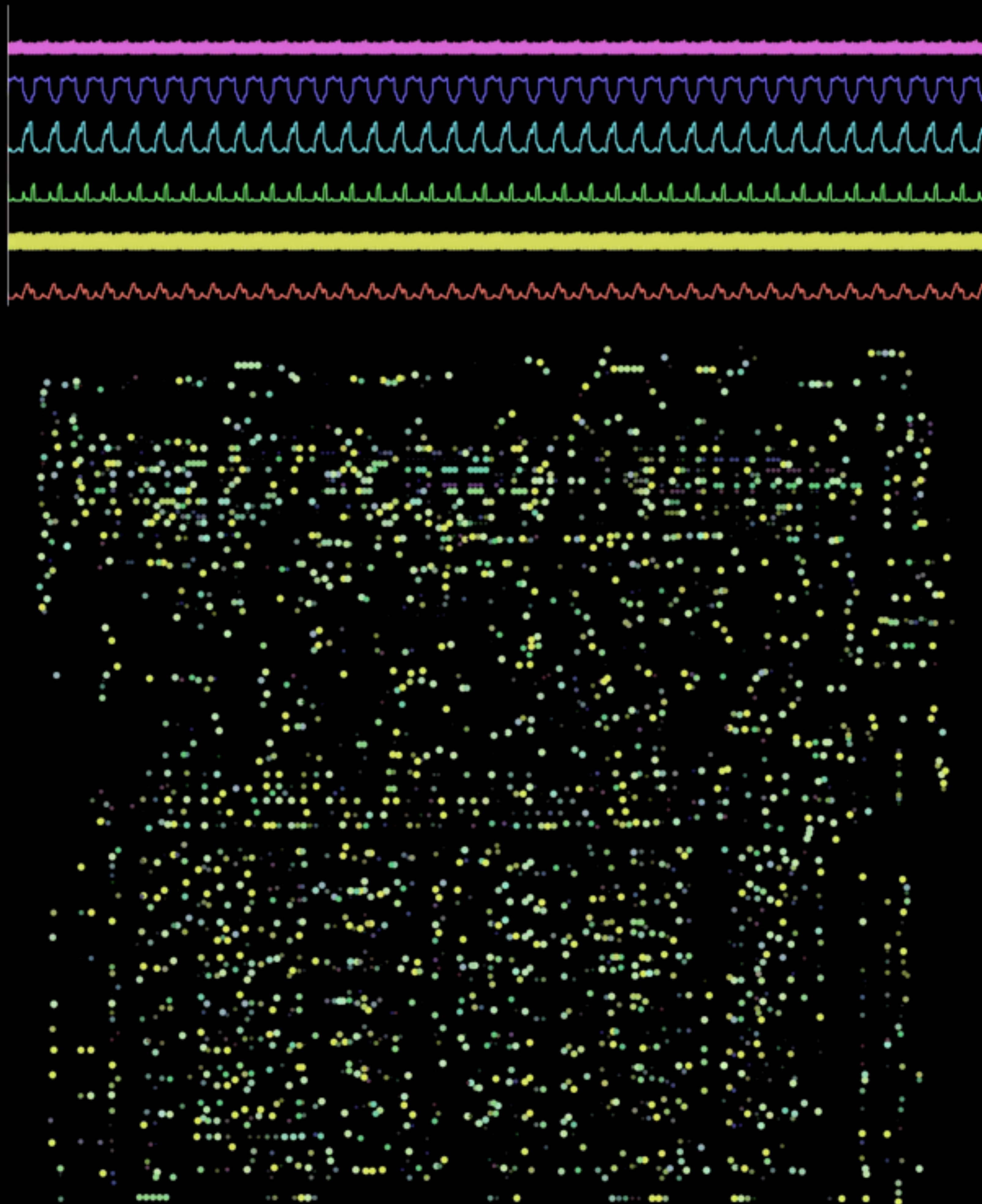
DIMENSIONALITY REDUCTION

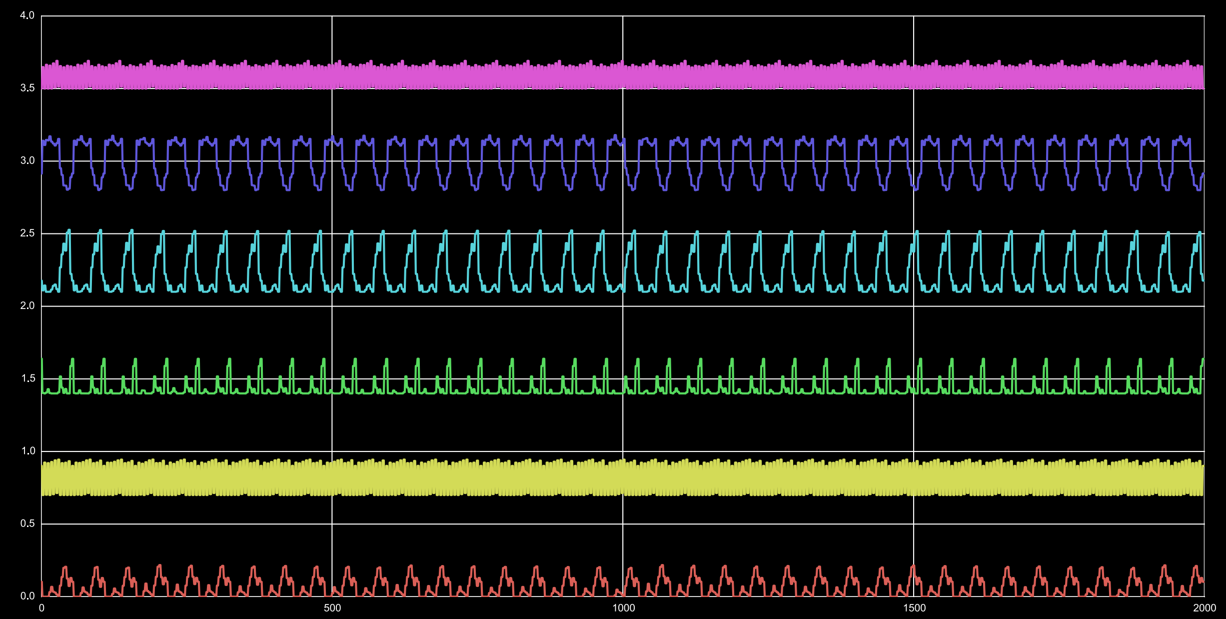


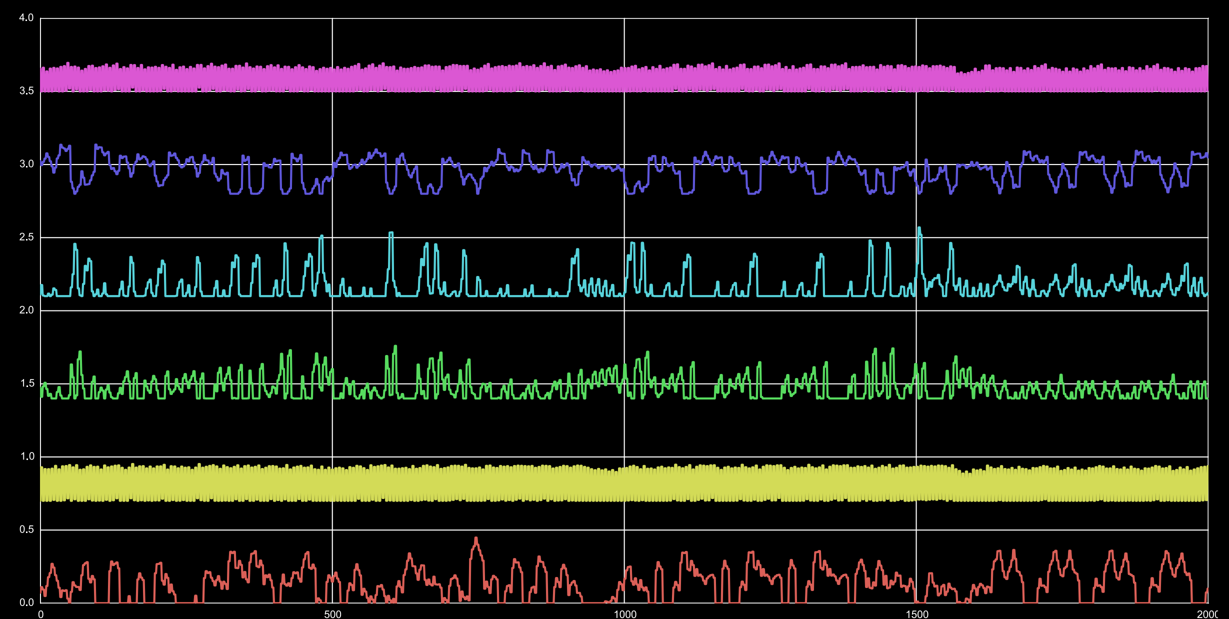
DIMENSIONALITY REDUCTION








4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
500
1000
1500
2000


4.0
3.5
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2.0
1.5
1.0
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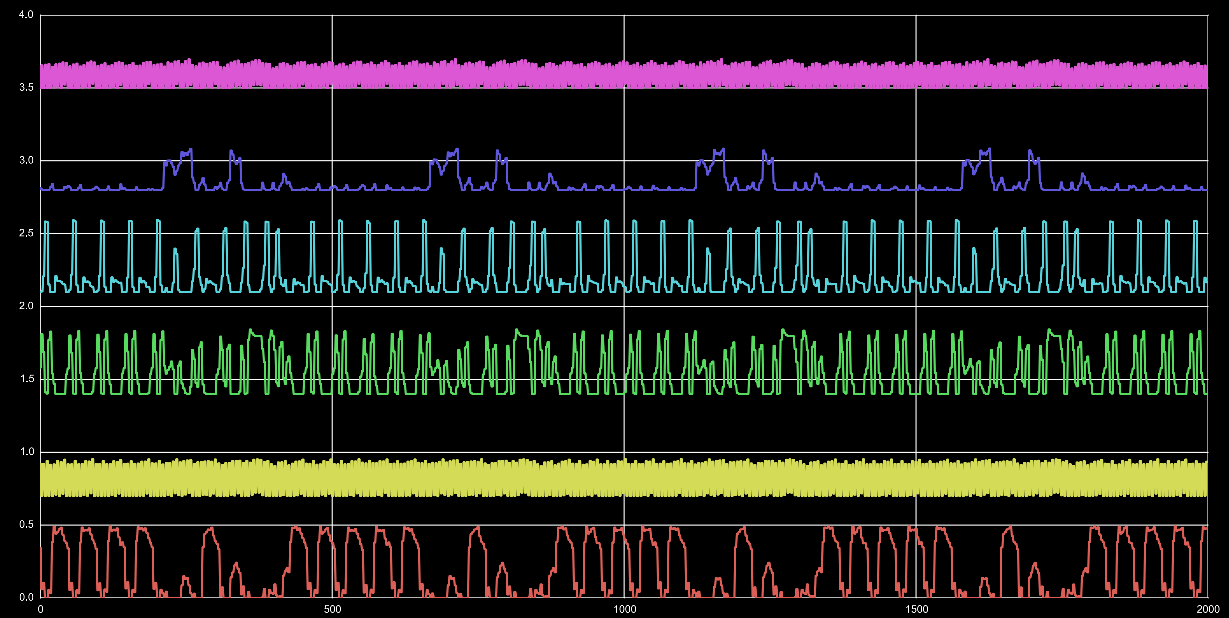
500
1000
1500


4.0
3.5
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2.0
1.5
1.0
0.5
0.0
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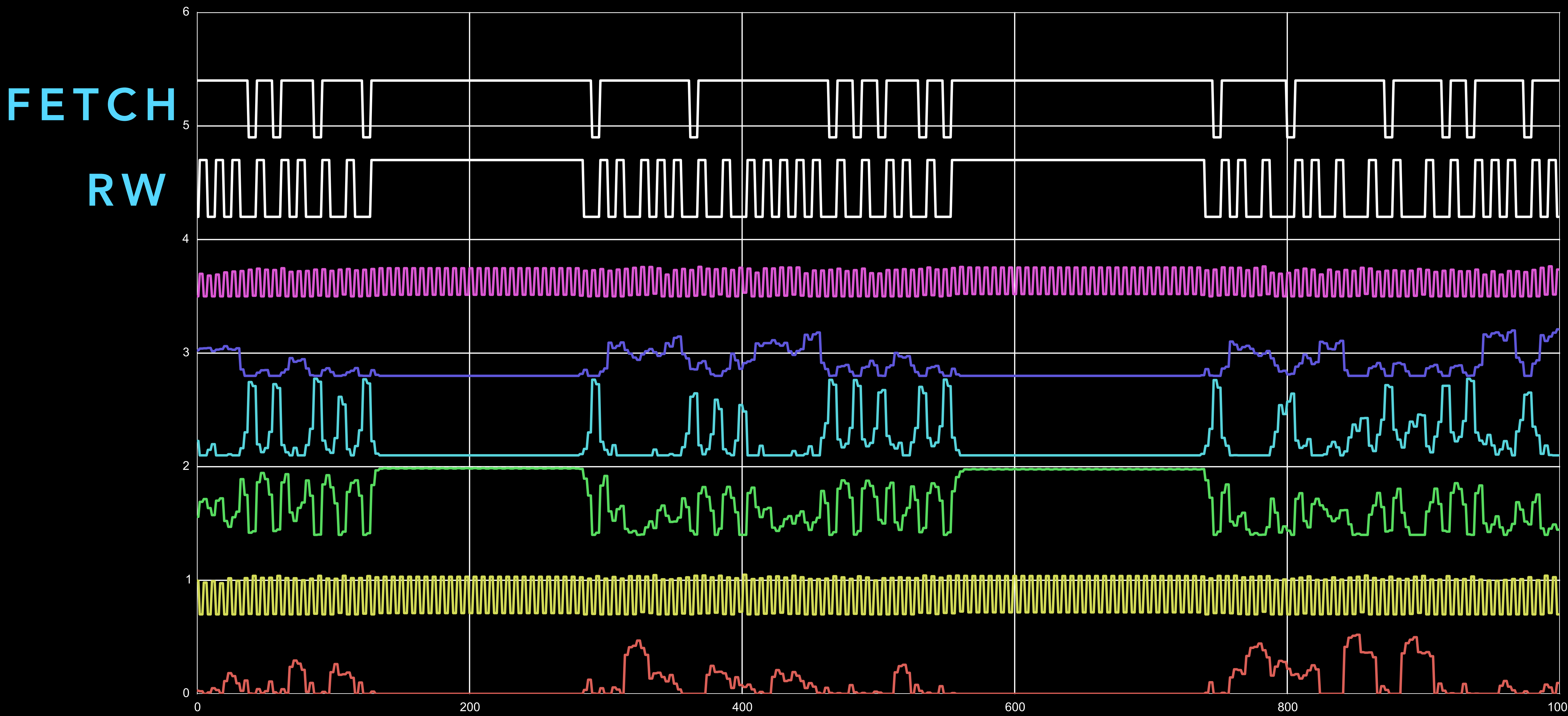
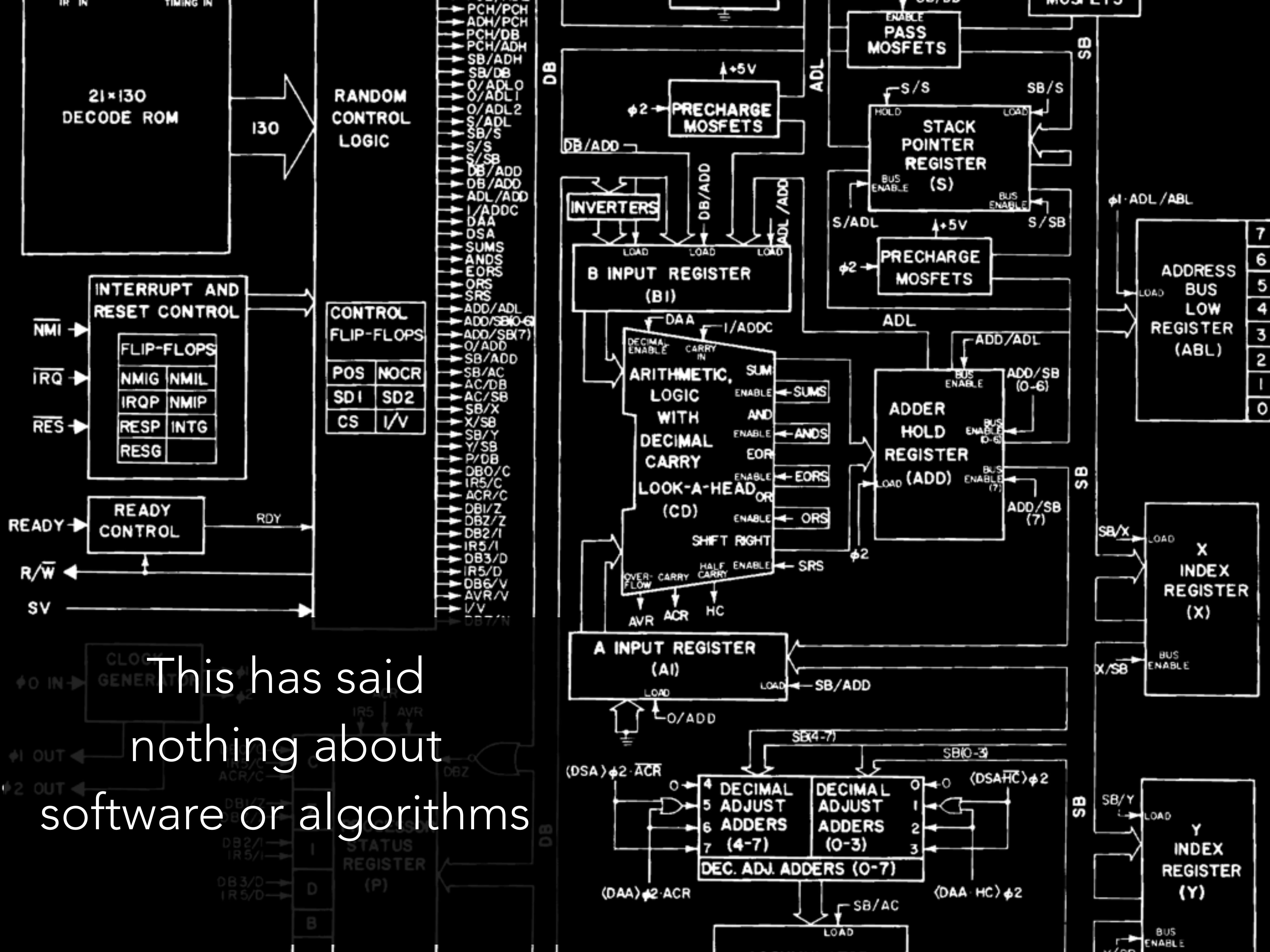
500
1000
1500
2000

WHAT ARE DIMENSIONS?



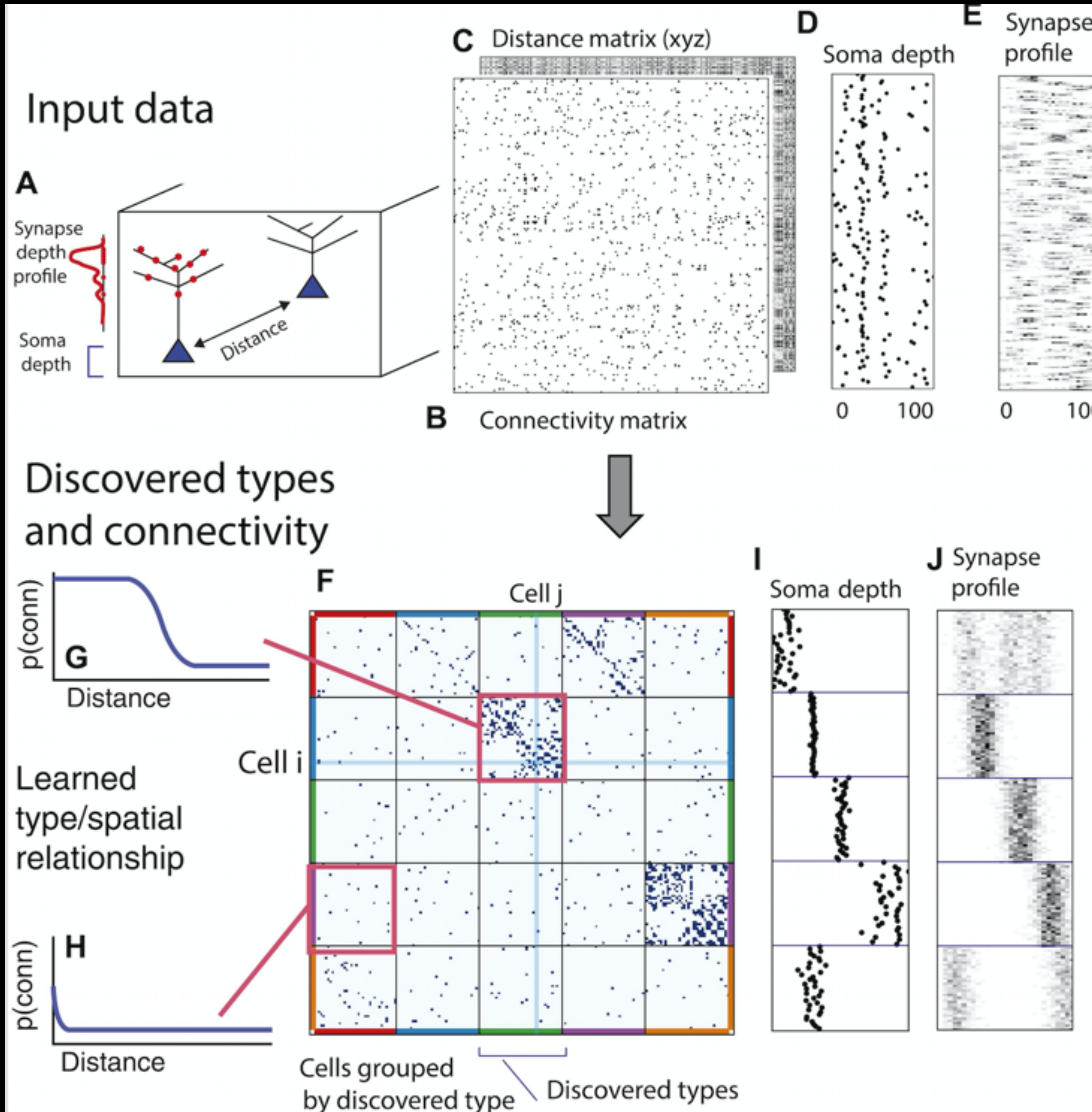
ALU
CLK0
IDL
ADH
ADL
X
Y
S
P
RDY
IR
AB
A
PD
ALUB
ALUA
CLK1OUT
RW
IDB
DOR
PCL
PCH
SYNC
DB
RES
0
1000
5000



This has said nothing about software or algorithms

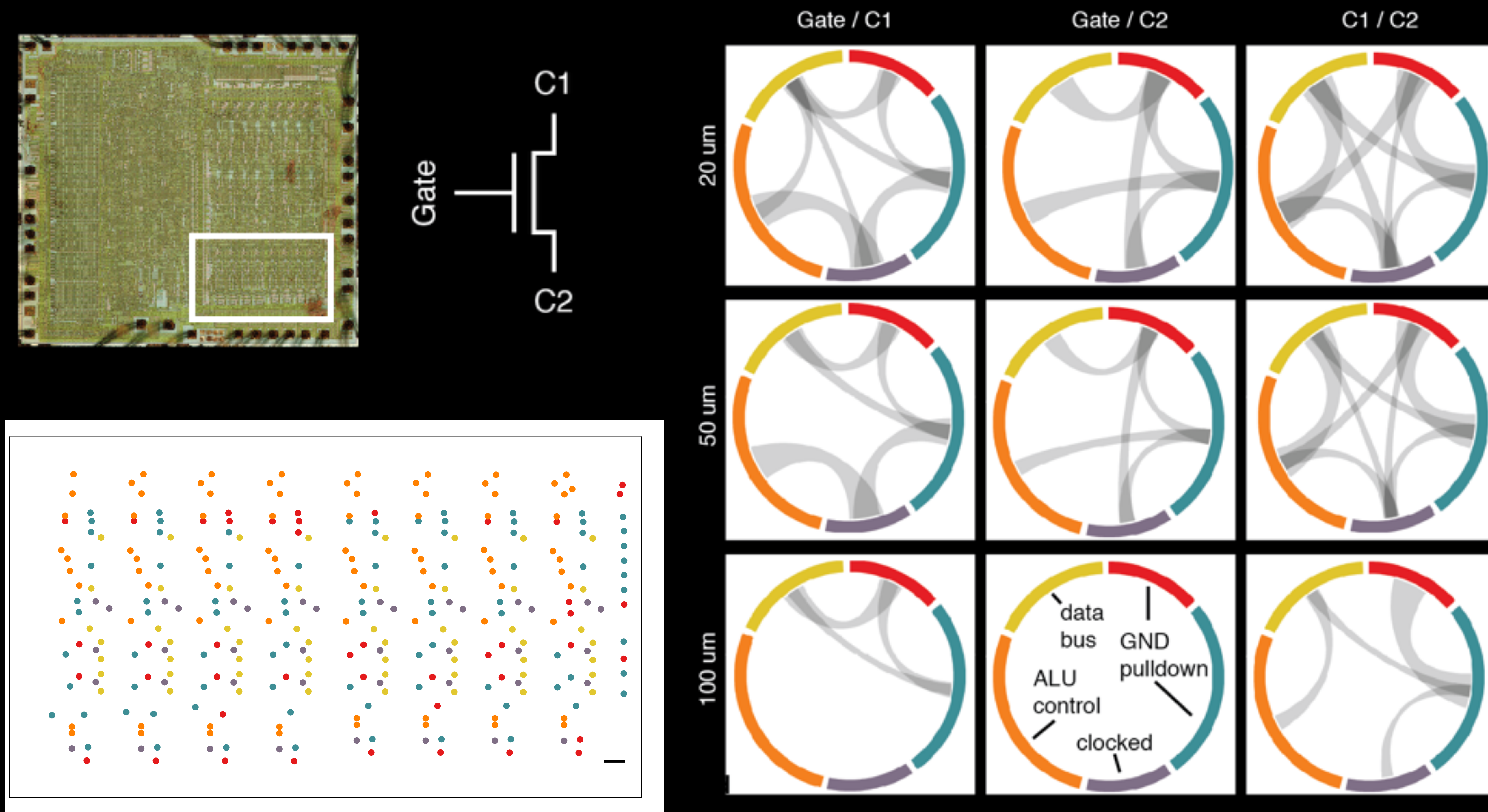
WHAT IS A STRUCTURED PROBABILISTIC MODEL

- Explicitly state your assumptions in the model (Bayesian)
- Write down a speculative model about how your data may have arisen
- Test the model



Input data
A
Synapse depth profile
Soma depth
Distance
C
Distance matrix (xyz)
B
Connectivity matrix
D
Soma depth
0
100
E
Synapse profile
0
100
Discovered types and connectivity
G
p(conn)
Distance
Learned type/spatial relationship
H
p(conn)
Distance
F
Cell j
Cell i
Cells grouped by discovered type
Discovered types
I
Soma depth
J
Synapse profile

CONNECTOMICS



JONAS, KORDING. AUTOMATIC DISCOVERY OF CELL TYPES FROM NEURAL CONNECTOMICS. *ELIFE 2015, APRIL 30, 2015*

STRUCTURED TIME SERIES

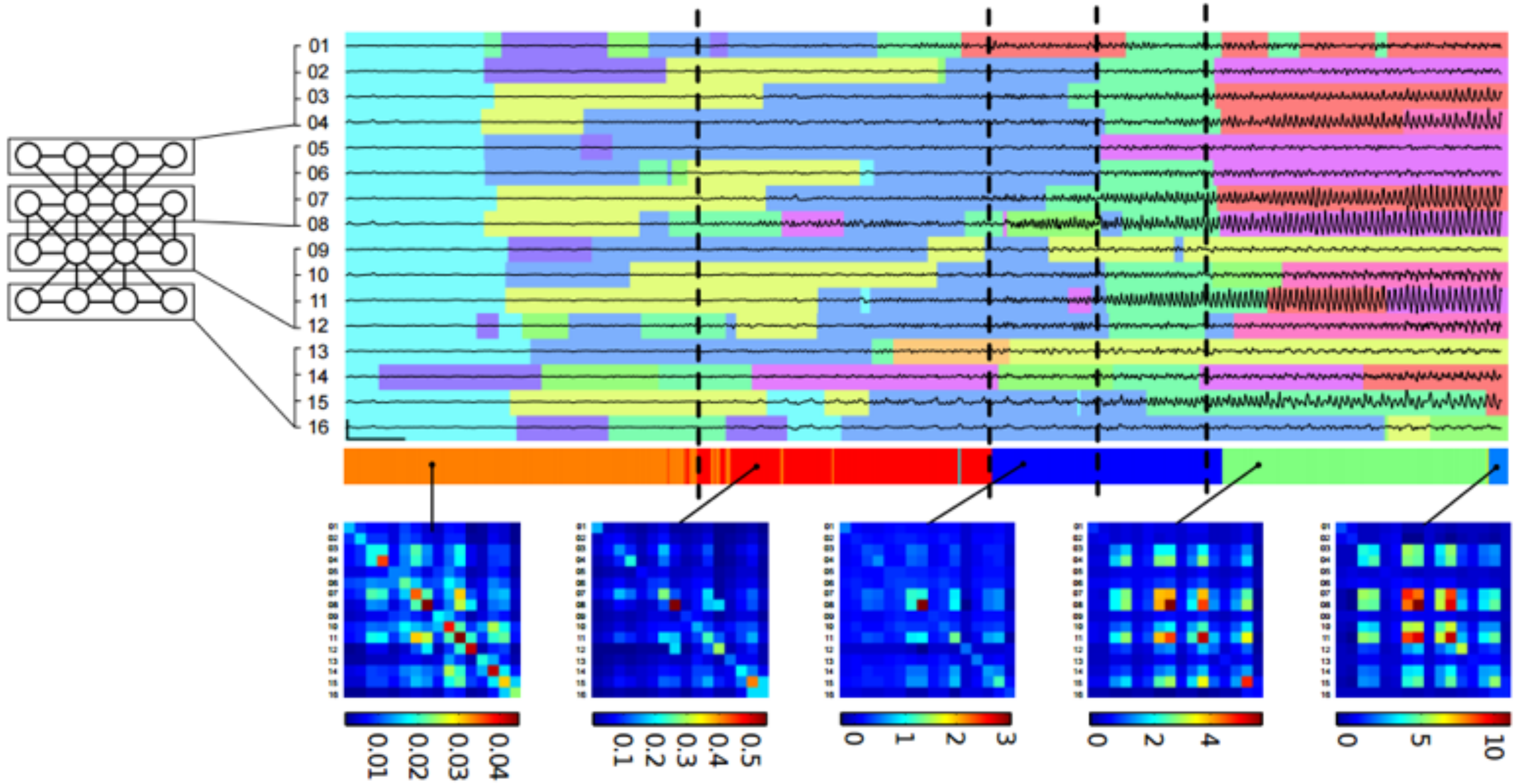
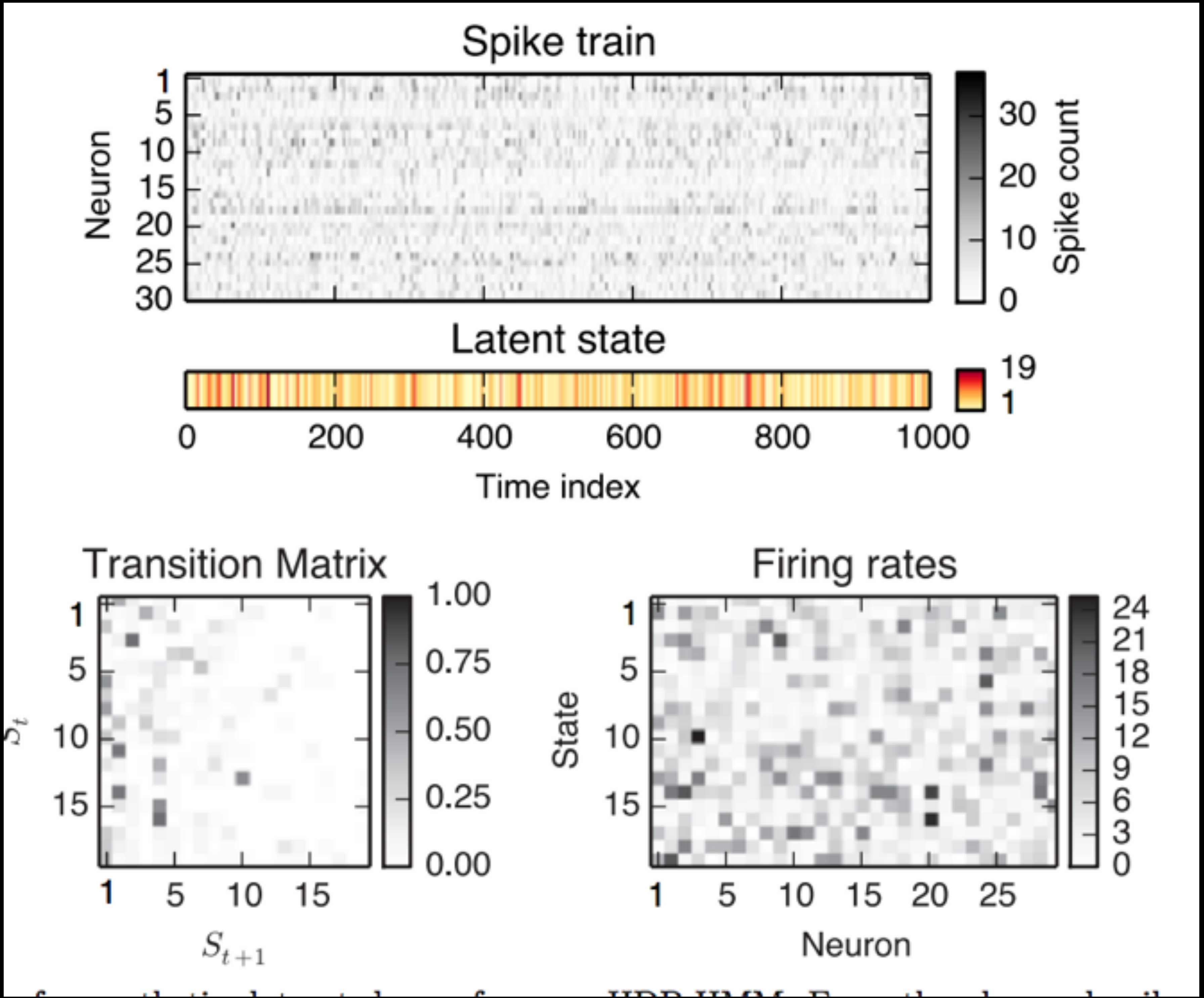


Figure 5: The graph used for a 16 channel iEEG electrode and corresponding traces over 25 seconds of a seizure onset with colors indicating the inferred channel states. The event states are shown below along with the associated innovation covariances. Vertical dashed lines indicate the EEG transition times marked independently by an epileptologist. Vertical and horizontal scale bars denote 1 mV and 1 second, respectively.

WULSIN, FOX, LITT. MODELING THE COMPLEX DYNAMICS AND CHANGING CORRELATIONS OF EPILEPTIC EVENTS. [HTTP://ARXIV.ORG/ABS/1402.6951](http://arxiv.org/abs/1402.6951)

STRUCTURED TIME SERIES



LINDERMAN, JOHNSON, WILSON, CHEN. A NONPARAMETRIC BAYESIAN APPROACH TO UNCOVERING RAT HIPPOCAMPAL POPULATION CODES DURING SPATIAL NAVIGATION. [HTTP://ARXIV.ORG/ABS/1411.7706](http://arxiv.org/abs/1411.7706)

THE DOWNSIDE

- These models are currently hard to write
- Hard to implement
- Inference does not scale well
- Come on, computer scientists, get with the program!