

Bradley Voytek, Ph.D.
UC San Diego

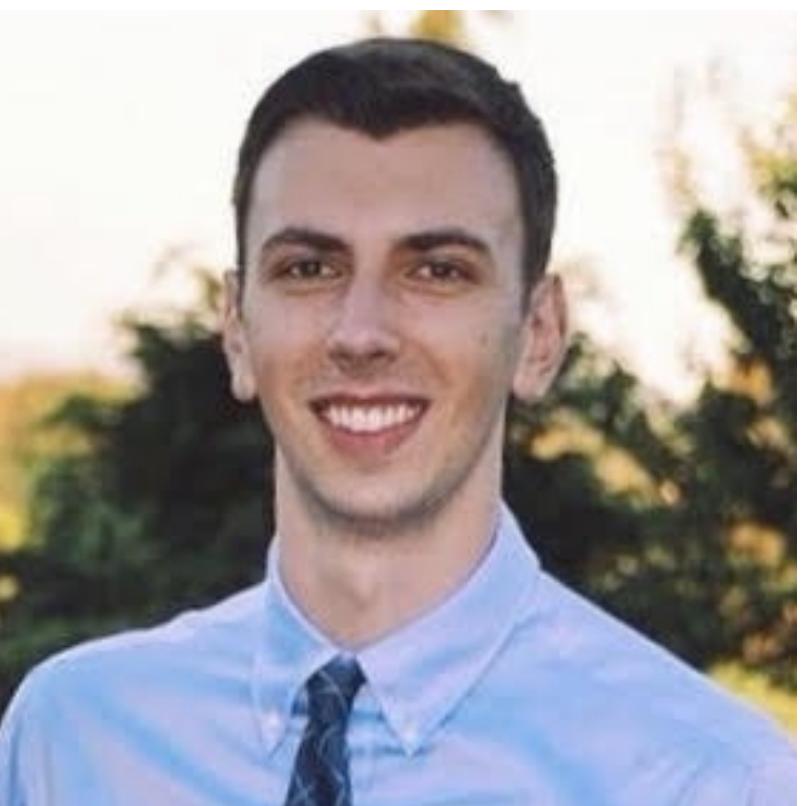
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VOYTEKlab

Andrew Bender
Neurosciences Ph.D. student



Blanca Burgos-Martin
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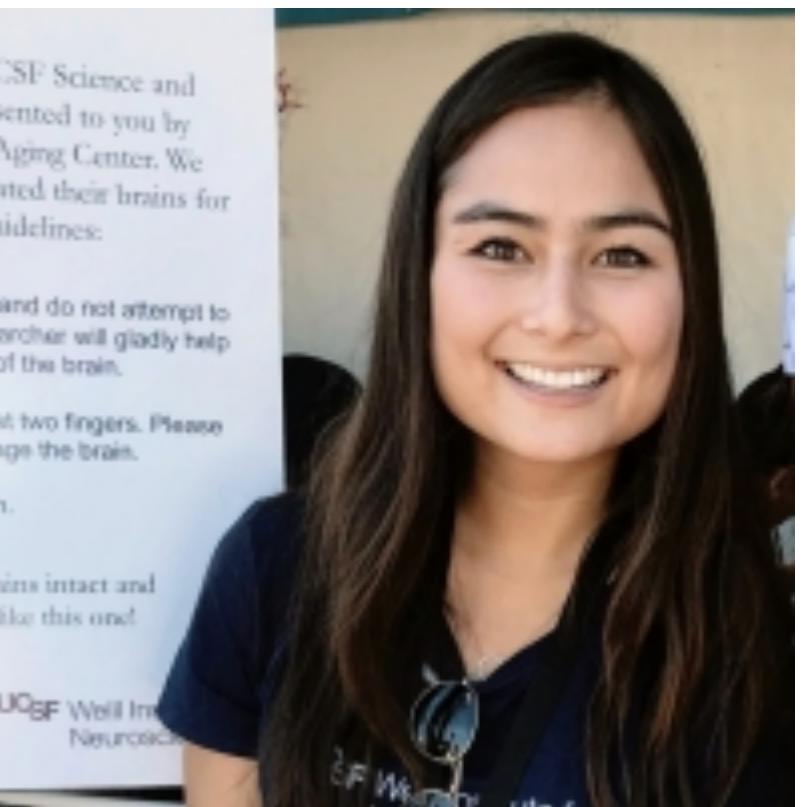
Quirine van Engen
Cogsci Ph.D. student



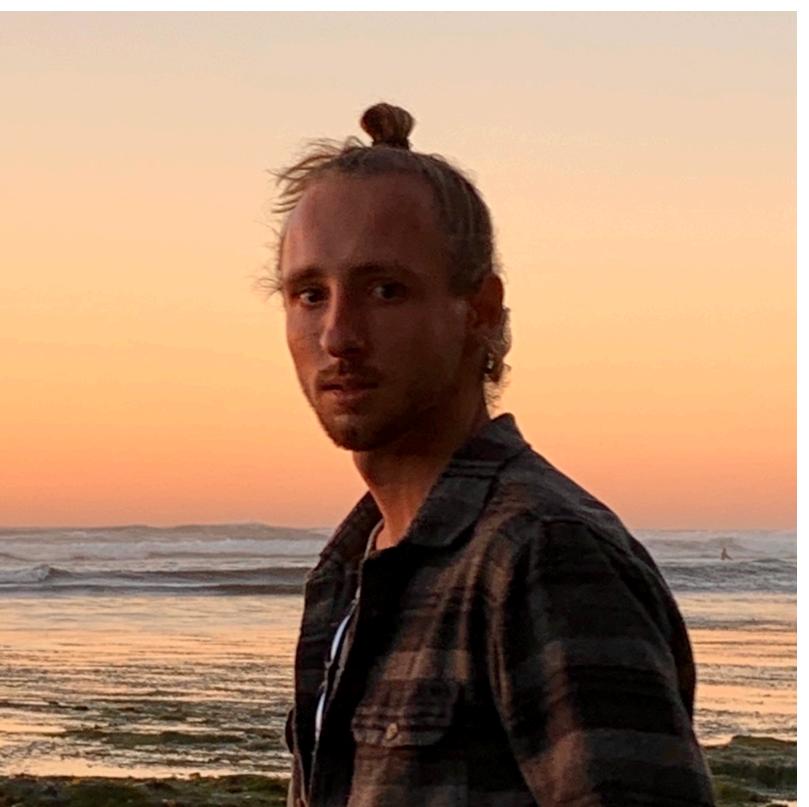
Ryan Hammonds
Data Science Ph.D. student



Eena Kosik
Cogsci Ph.D. student



Trevor McPherson
Neurosciences Ph.D. student



Michael (MJ) Preston
Neurosciences Ph.D. student



Sydney Smith
Neurosciences Ph.D. student





OSCILLATIONS!

What's the problem?

Oscillations are correlated with everything

Oscillations are correlated with everything

Tens-of-thousands of oscillation papers

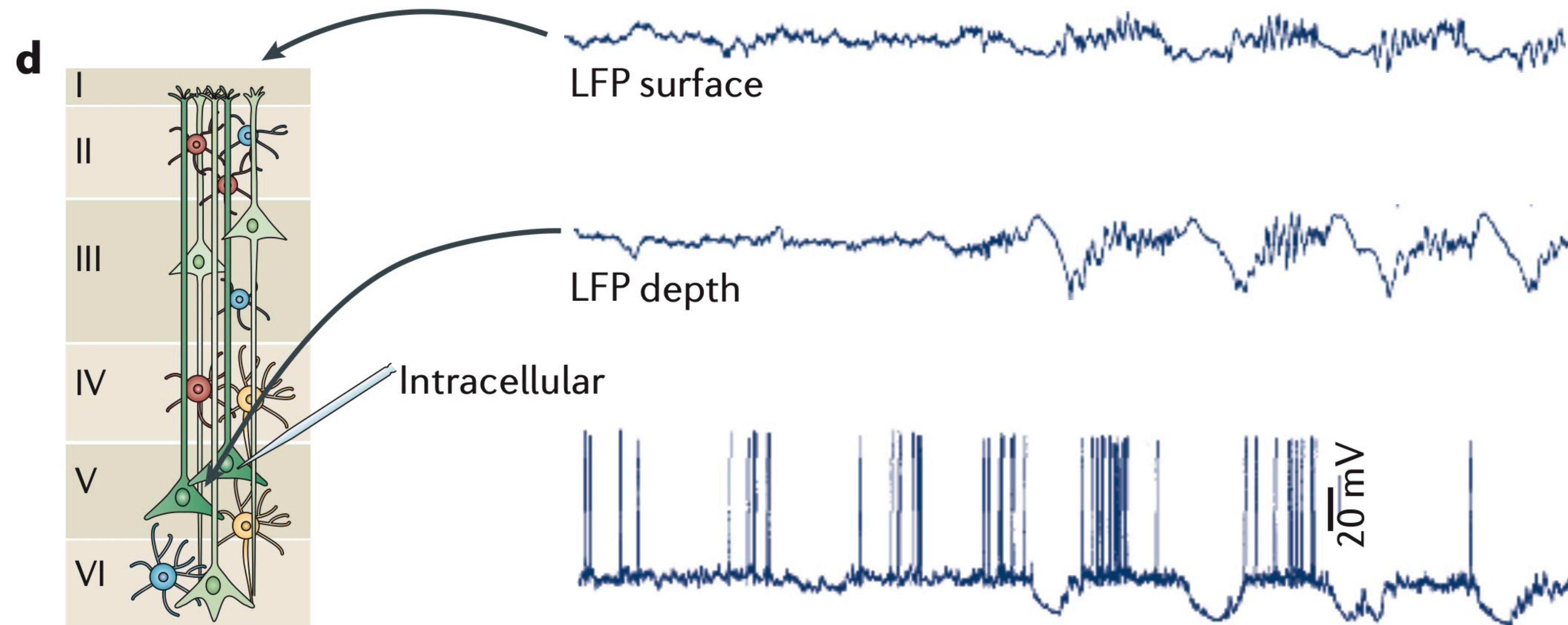
What is a neural oscillation?

**We can't talk about oscillations
without understanding**

- 1. Where they come from**
- 2. How they're traditionally measured**

I. Where do oscillations *come from?*

Origin of LFP / EEG



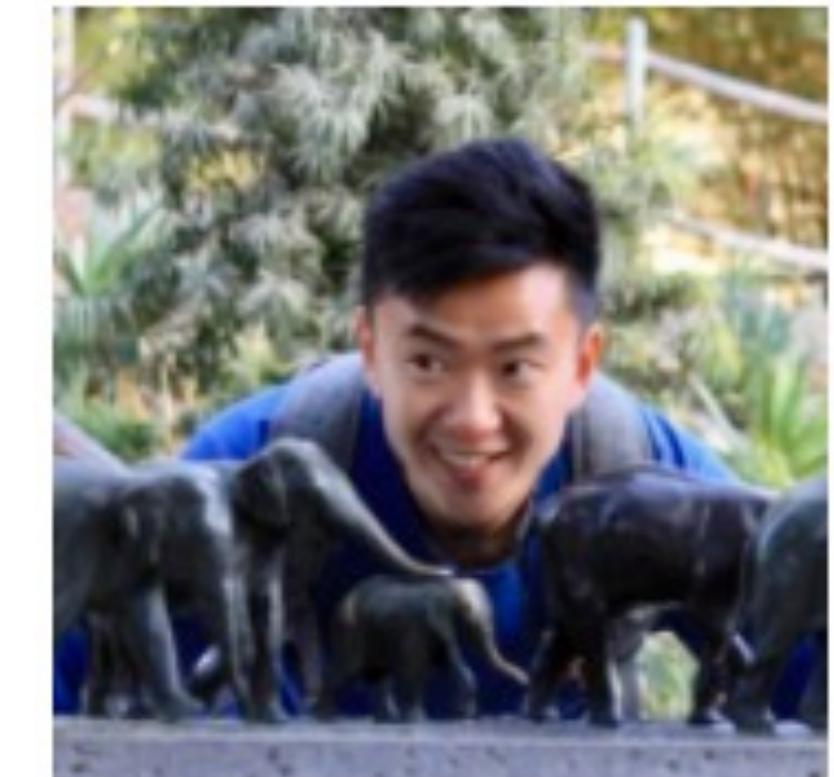
Largely driven by synaptic + transmembrane currents

Cortical organoids

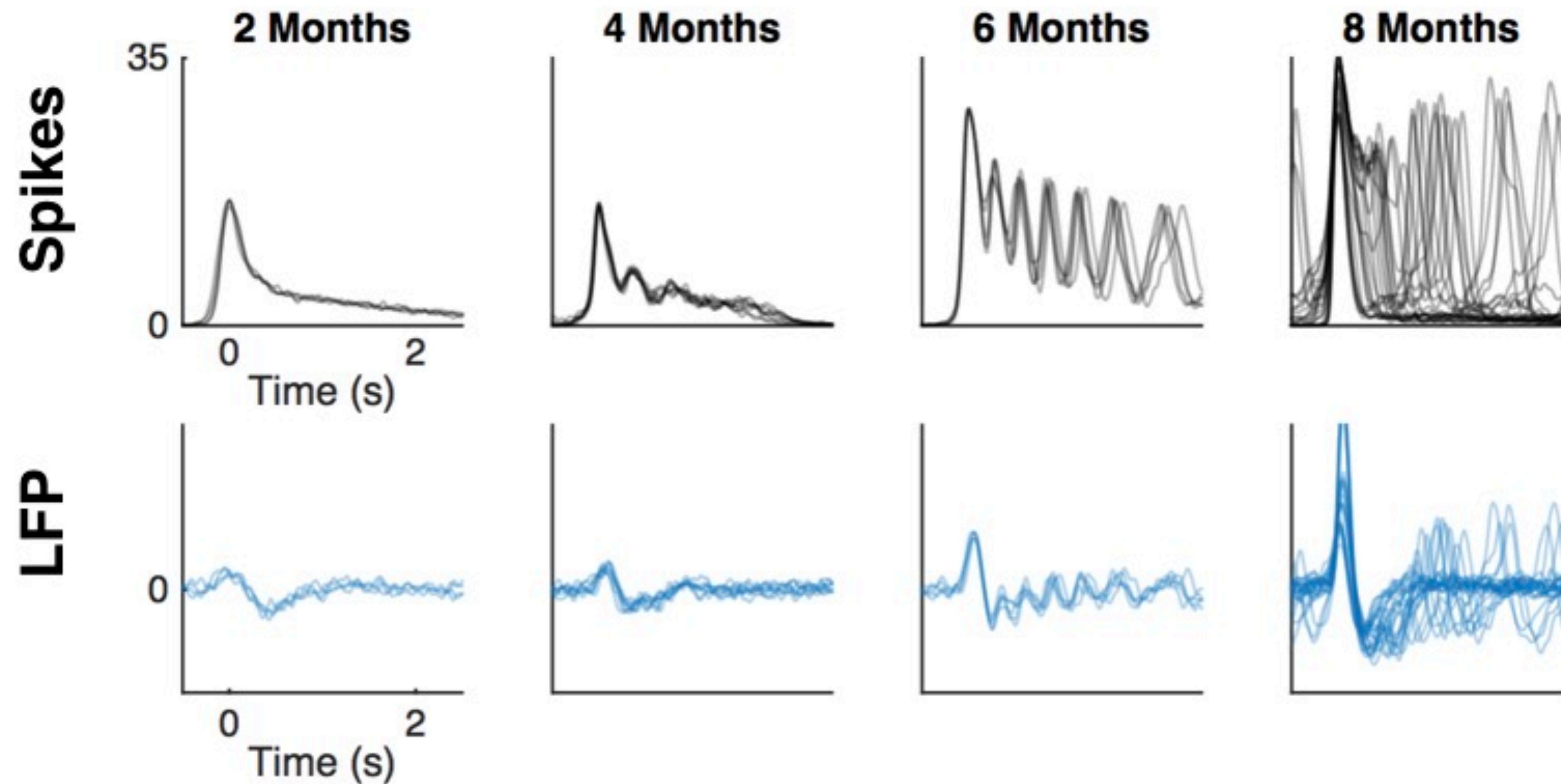


~ 4mm diameter
~ 100,000 neurons

Richard Gao

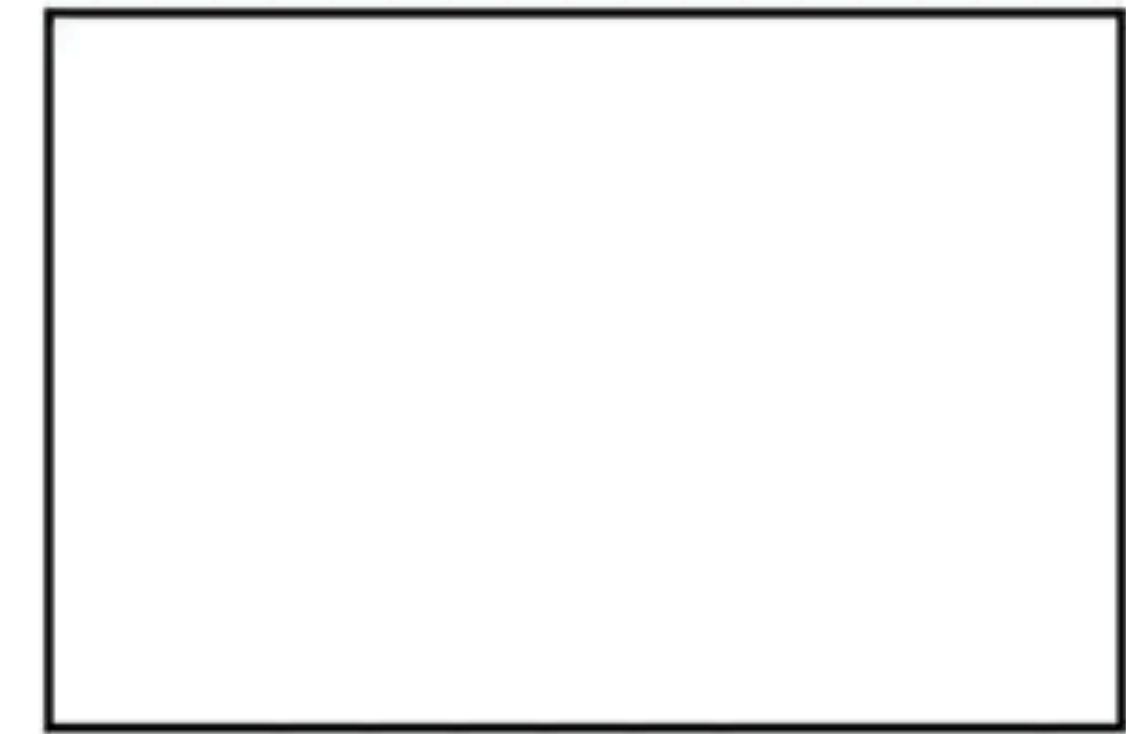
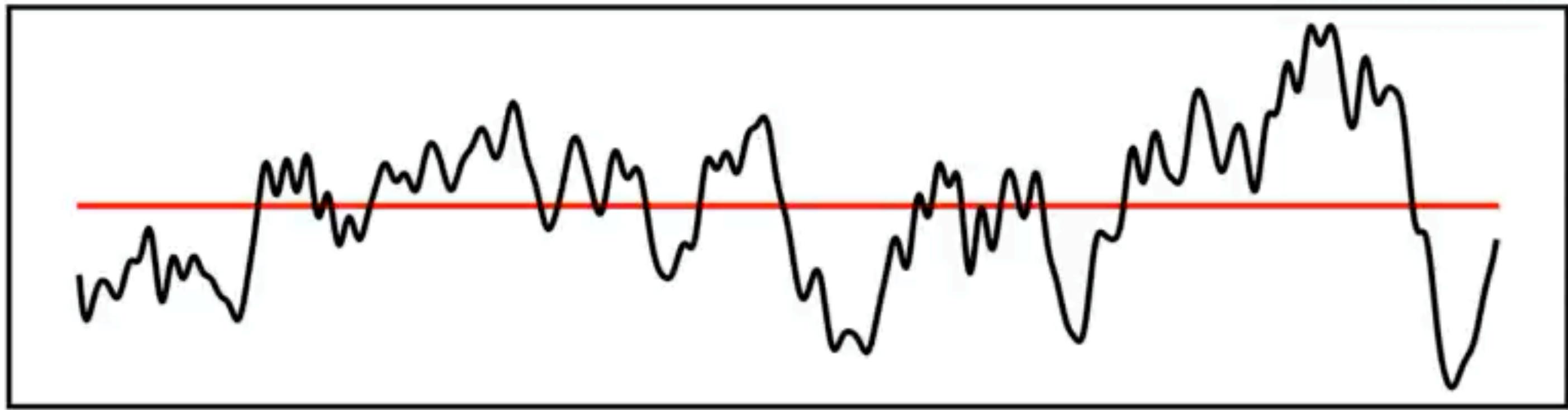
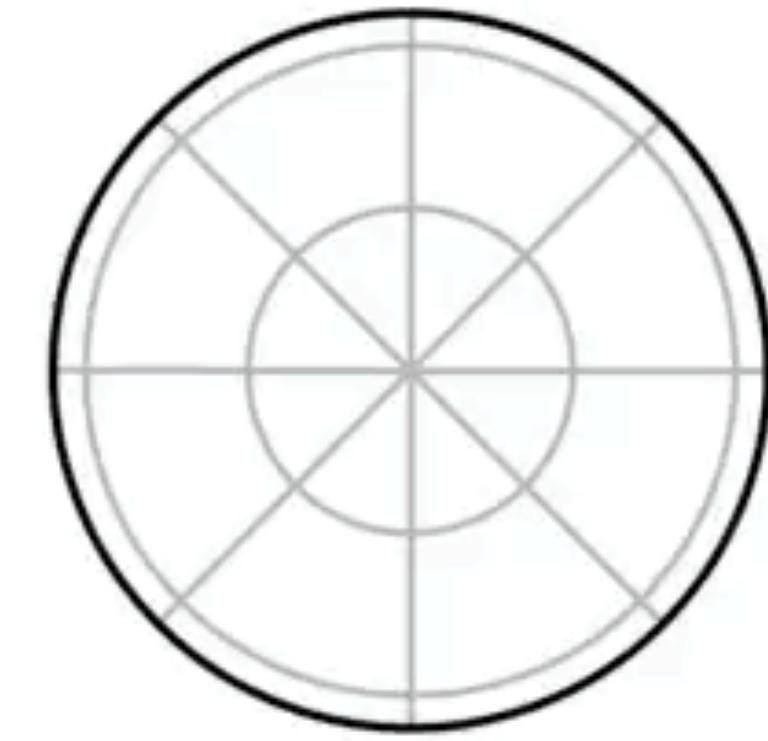
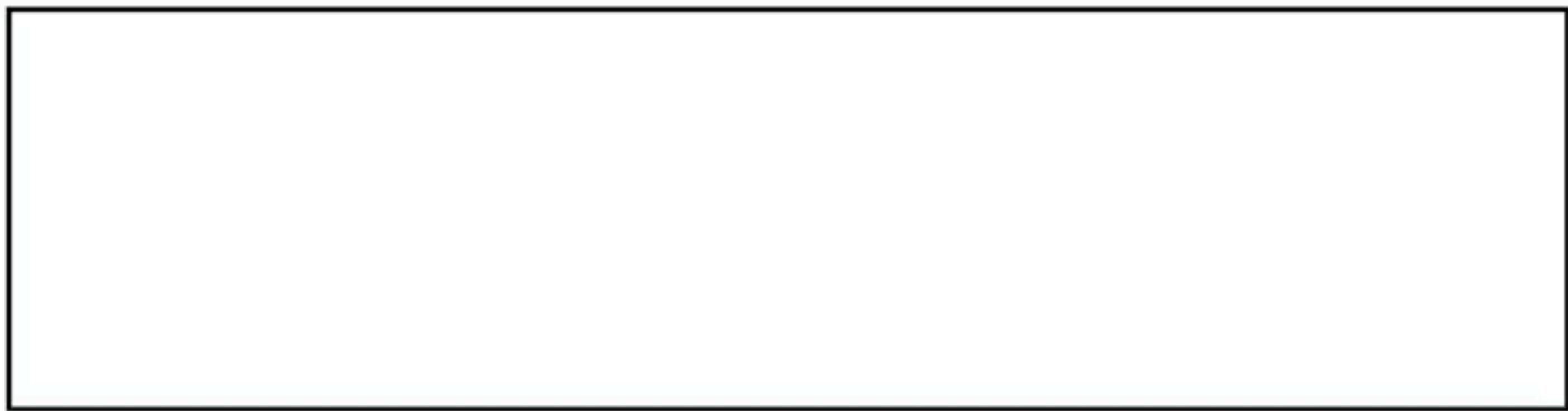


Origin of oscillations



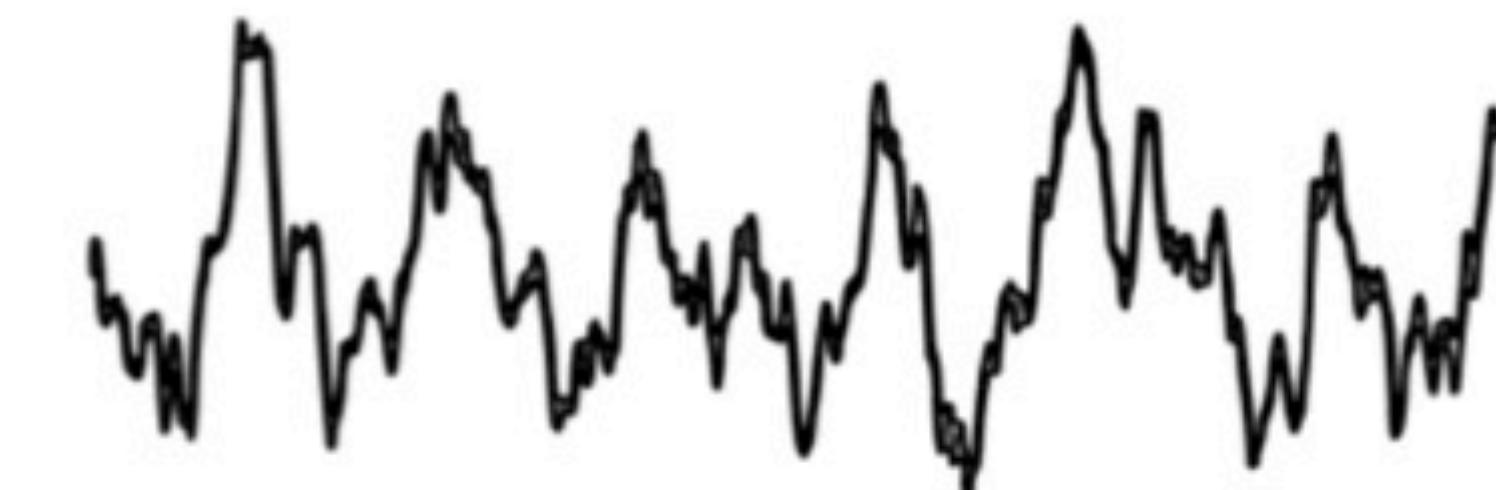
2. How are oscillations (traditionally) measured?

Measuring oscillations

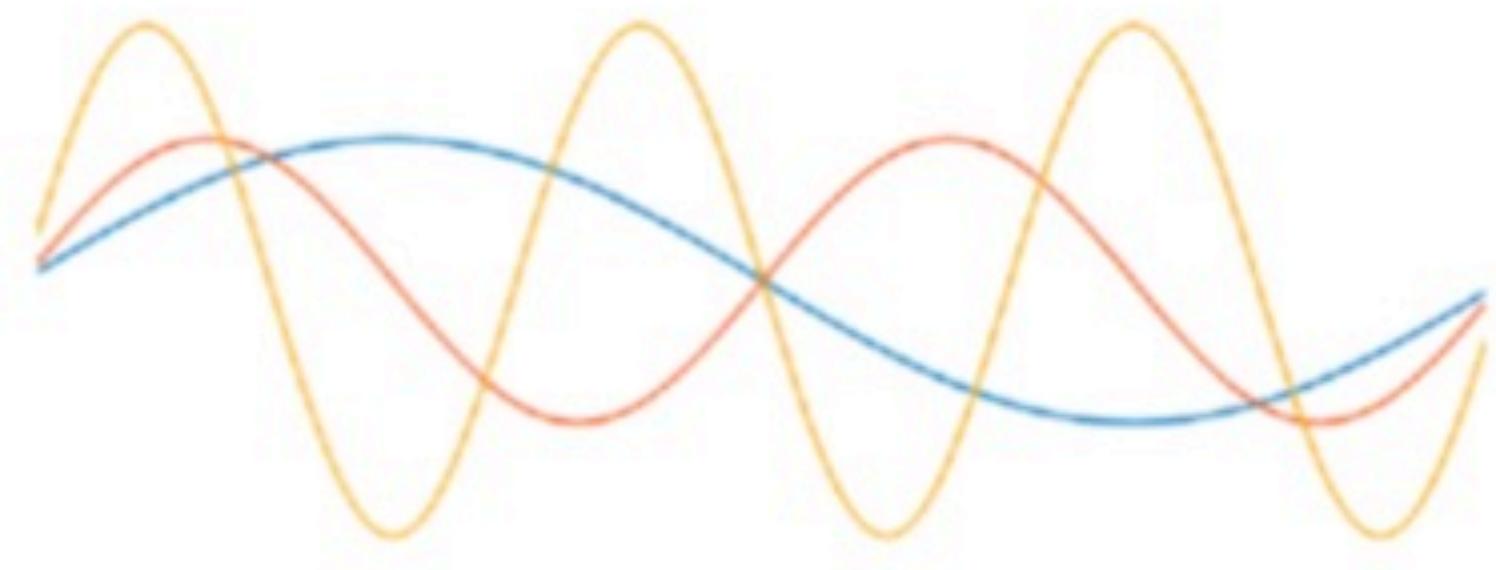


Measuring oscillations

Time Domain

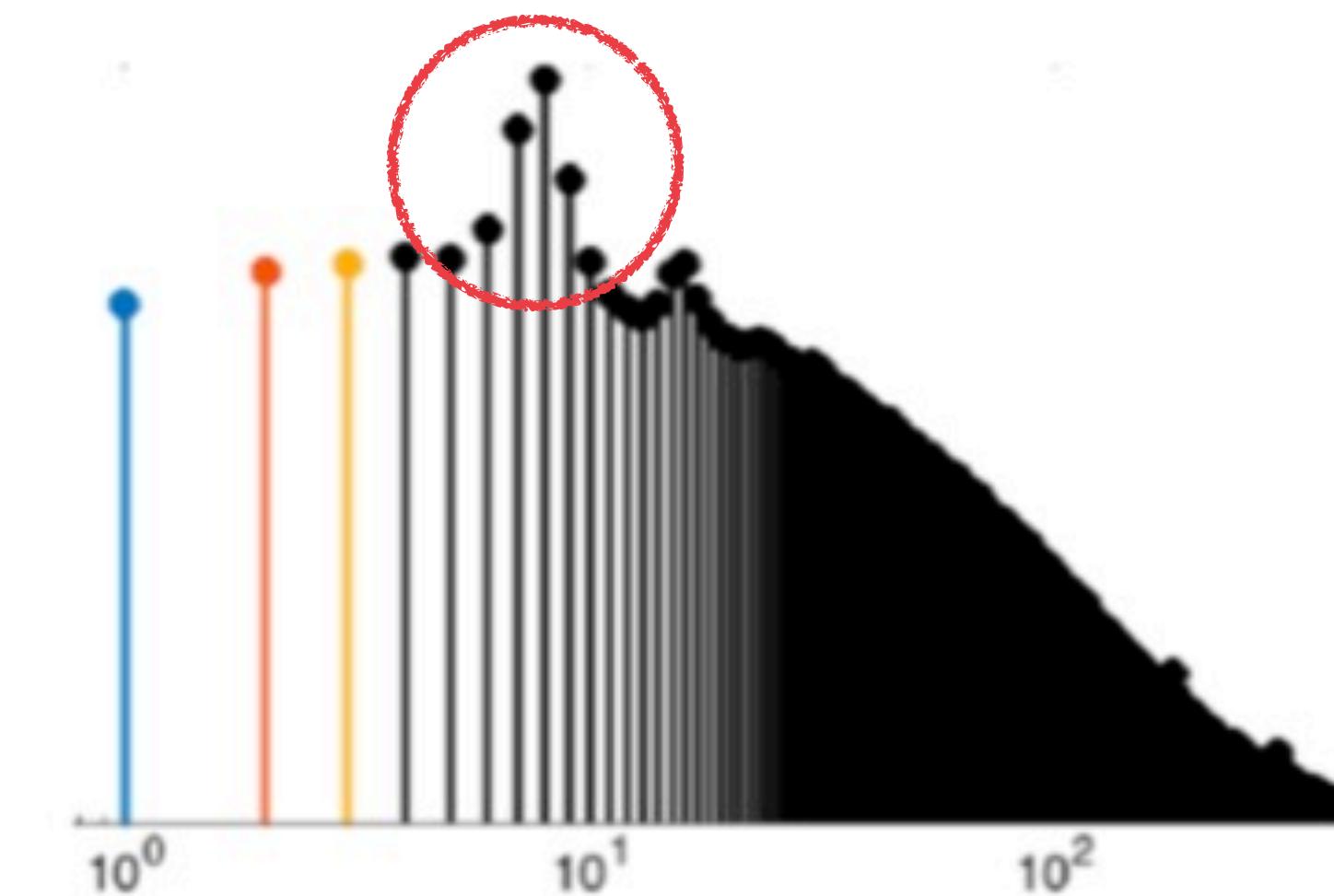


II



time (s)

Frequency Domain

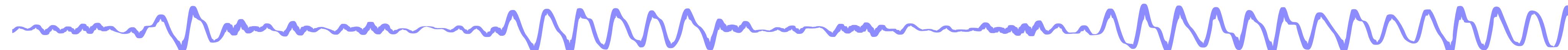
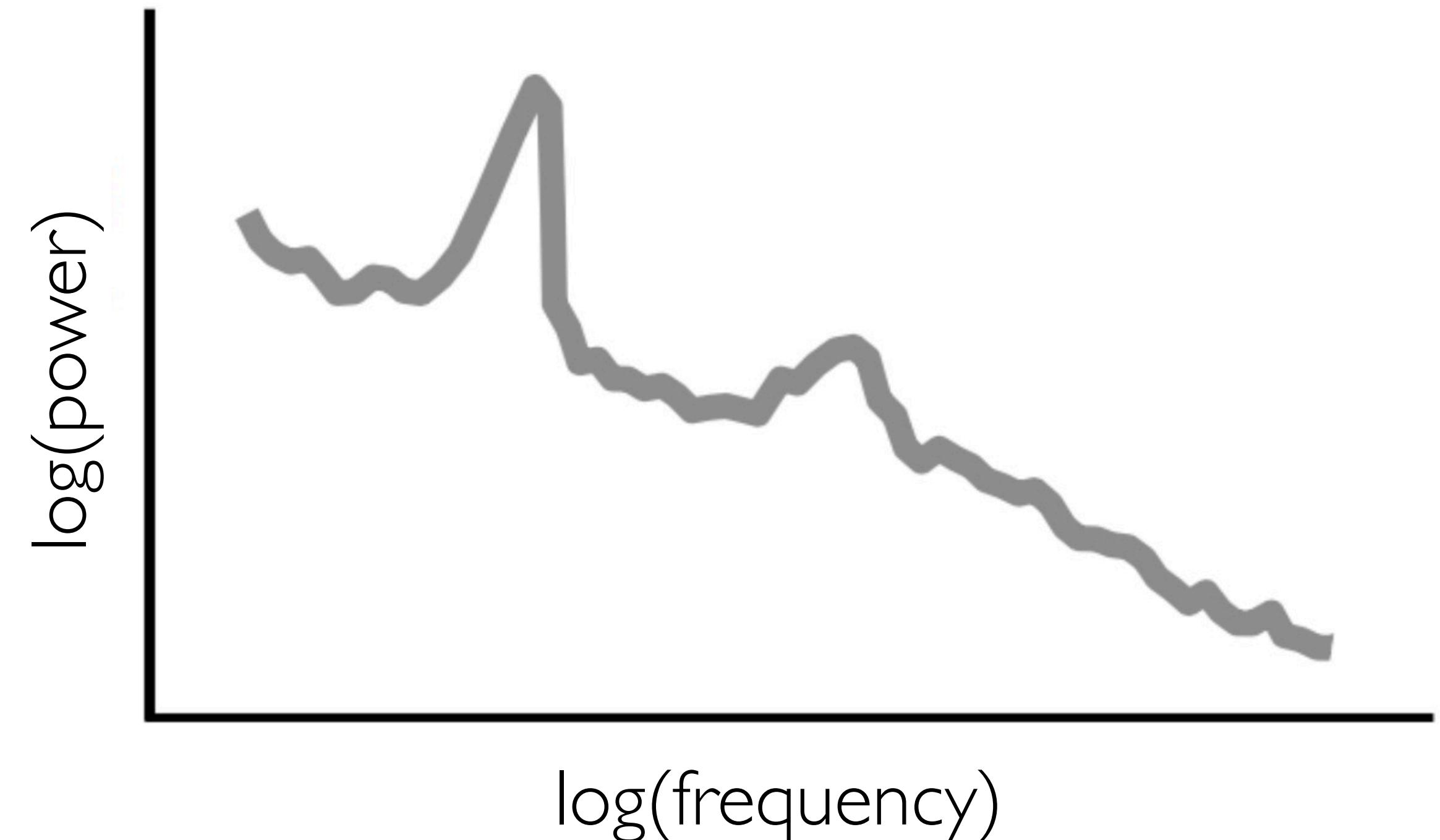


frequency (Hz)

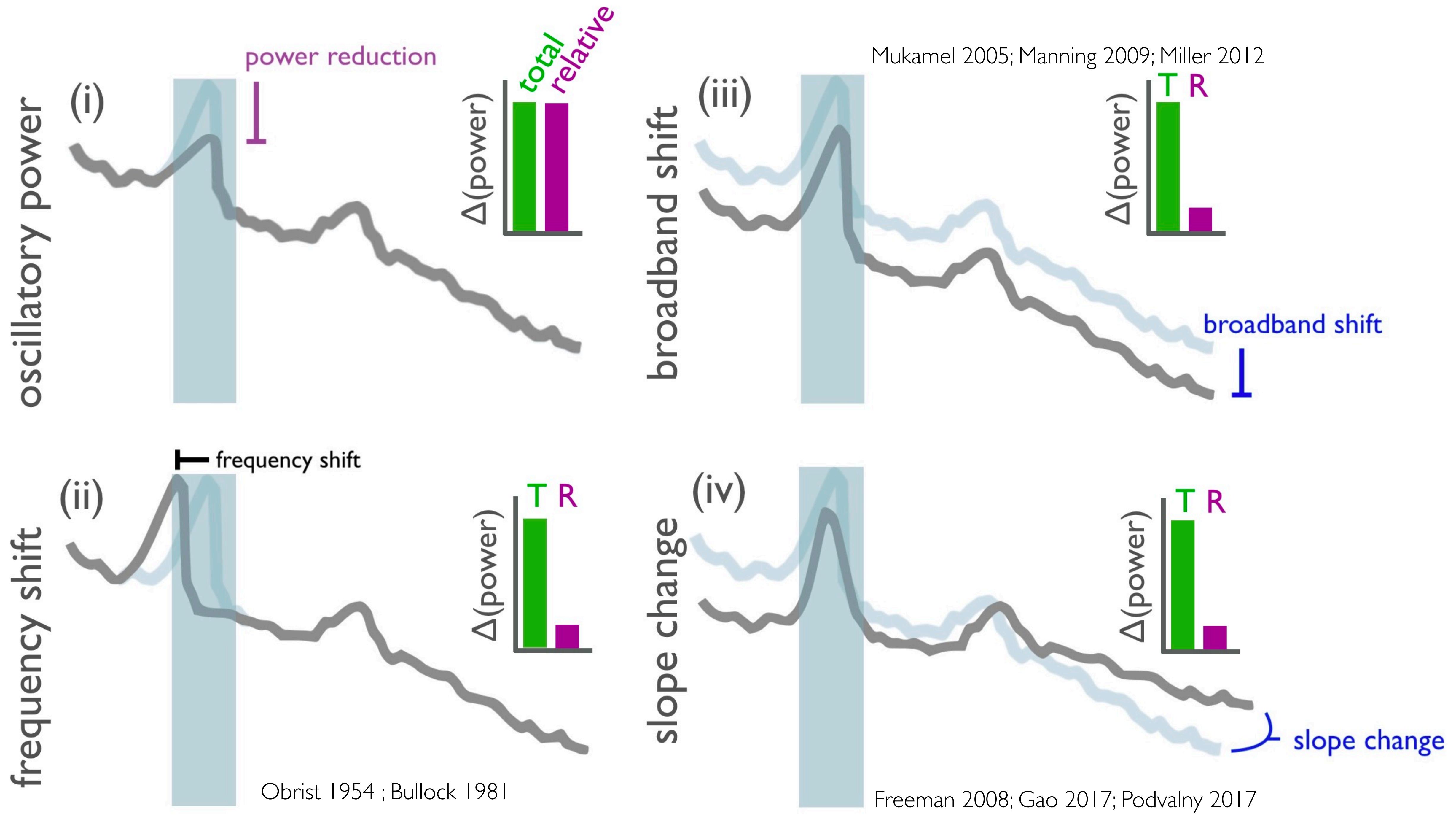
Oscillations are *bumps*

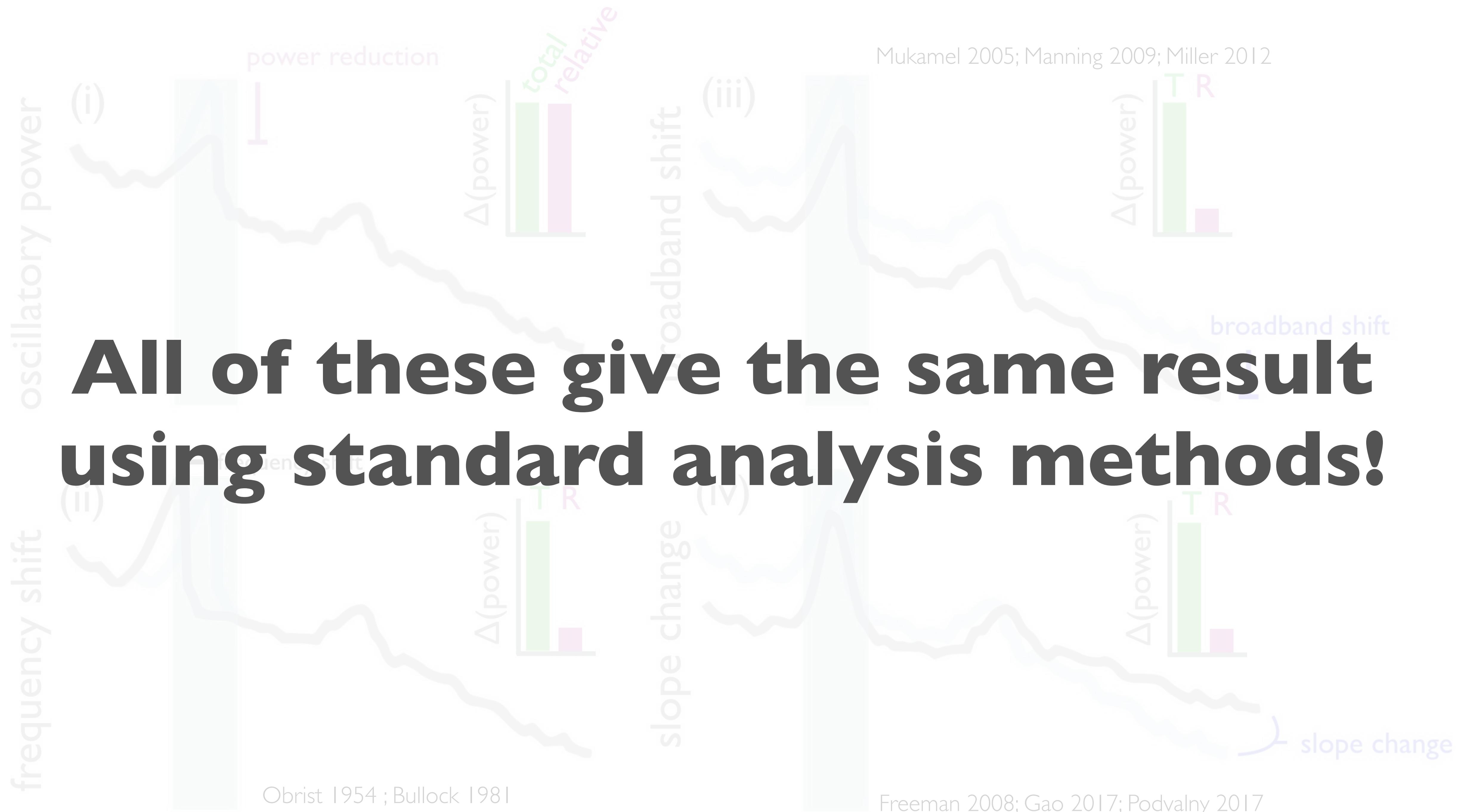
“In a power spectrum, brain oscillations appear as **bumps** on top of this $1/f$ slope...” - He B, *Trends Cogn Sci* 2014

“[when] particular oscillation frequencies become dominant... a peak (**bump**) appears in the respective frequency band.” - Buzsáki *et al.*, *Neuron* 2013



What's the problem?





**We can't adjudicate between these
without careful parameterization**

What's a solution?

Python!

pip install

- neurodsp (Cole et al., *J Open Source Softw* 2019)
- fooof (Donoghue, Haller, Peterson et al., *Nature Neurosci* 2020)

Thomas Donoghue, Ph.D.



Ryan Hammonds



Scott Cole, Ph.D.



Natalie Schawronkow, Ph.D.



Parameterize our spectra!

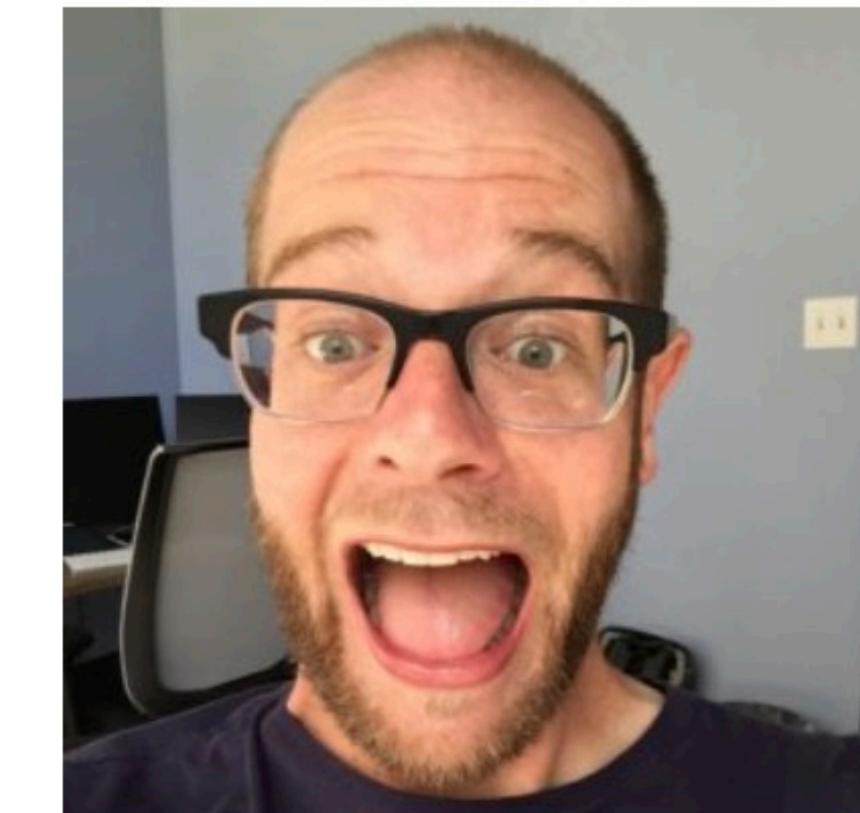
Tom Donoghue, Ph.D.



Matar Haller, Ph.D. & Avgusta Shestyuk, Ph.D.



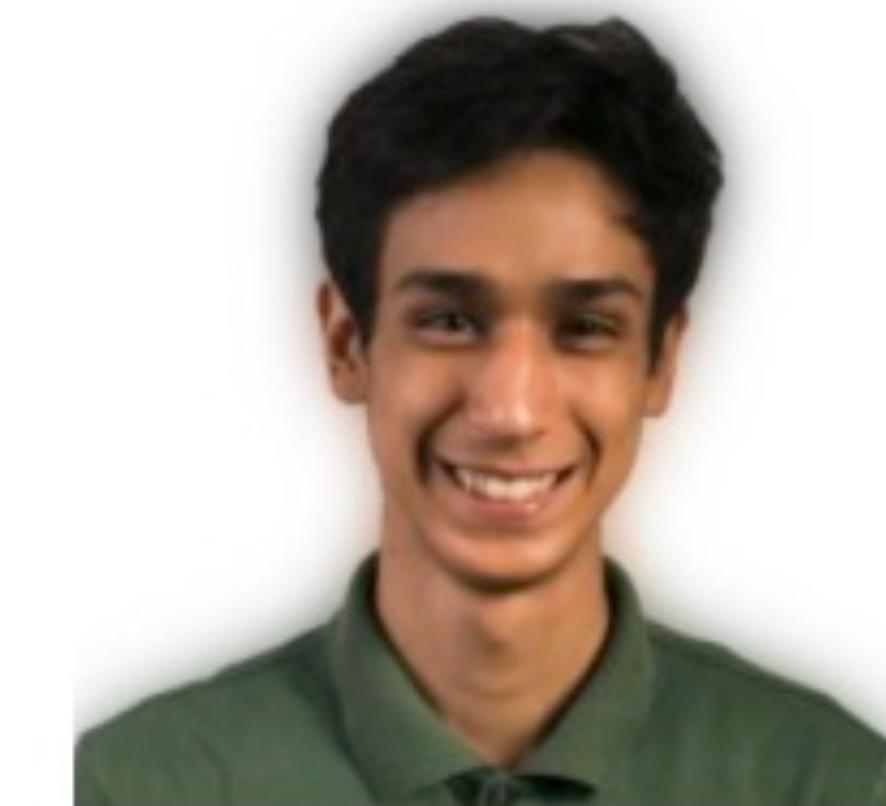
Erik Peterson, Ph.D.



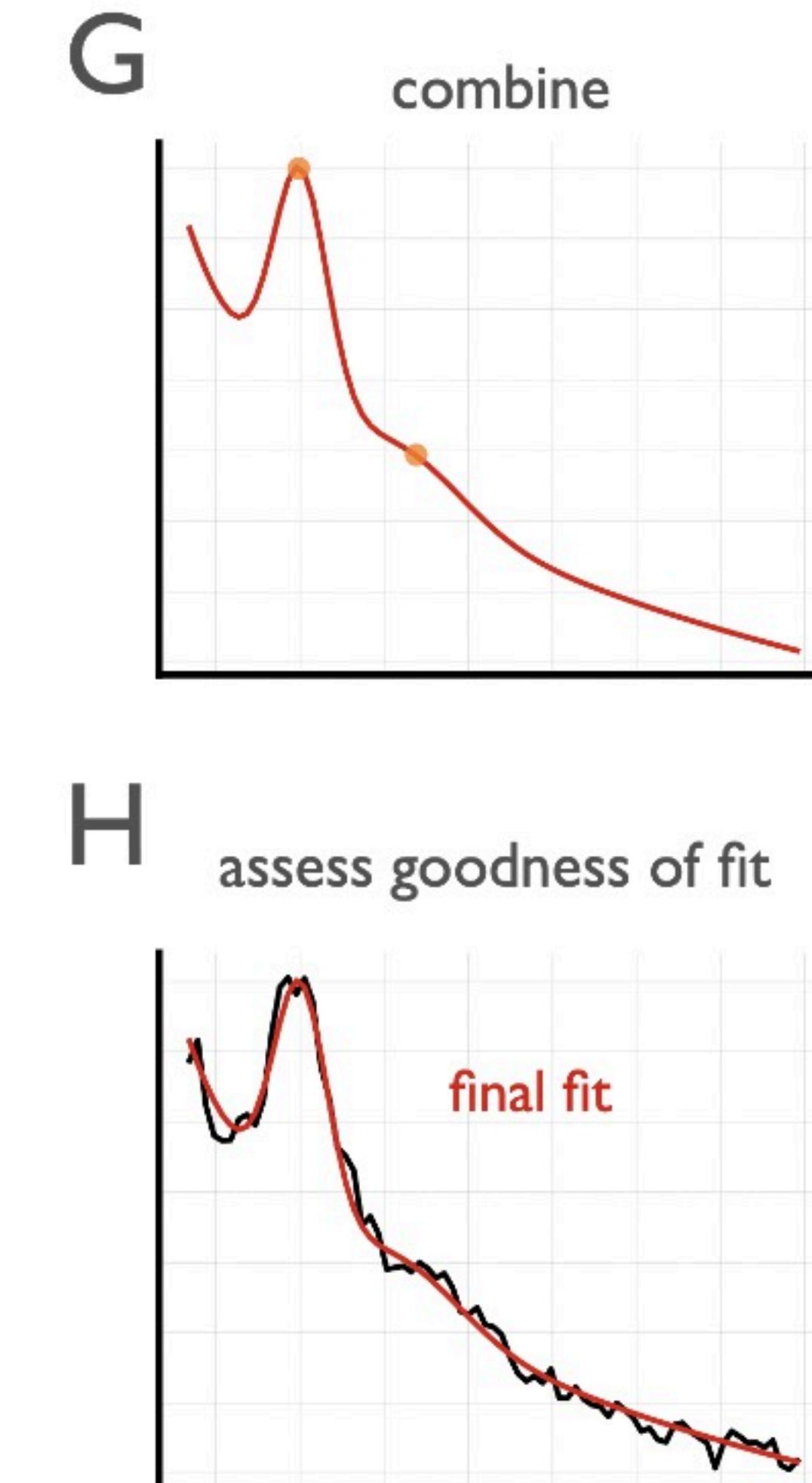
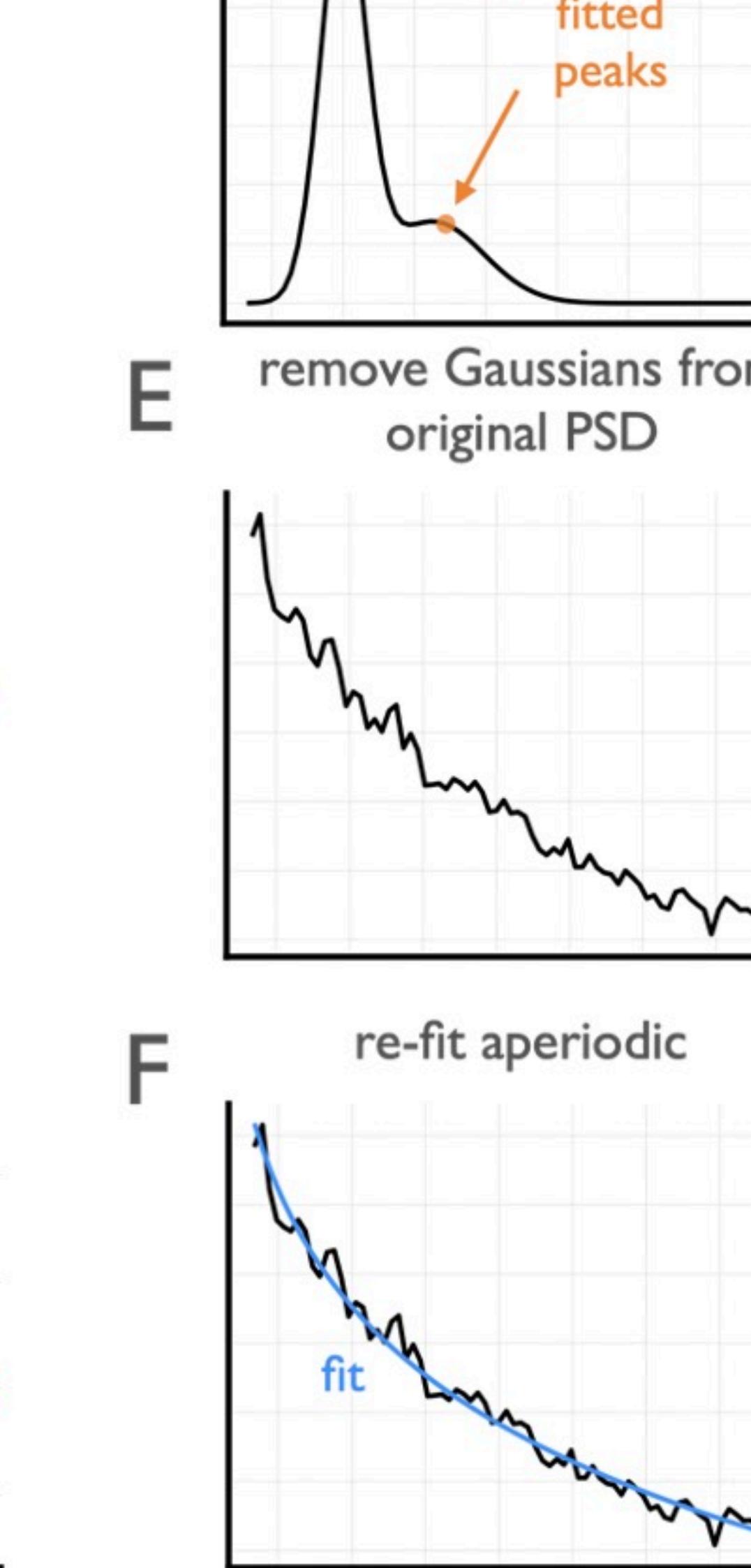
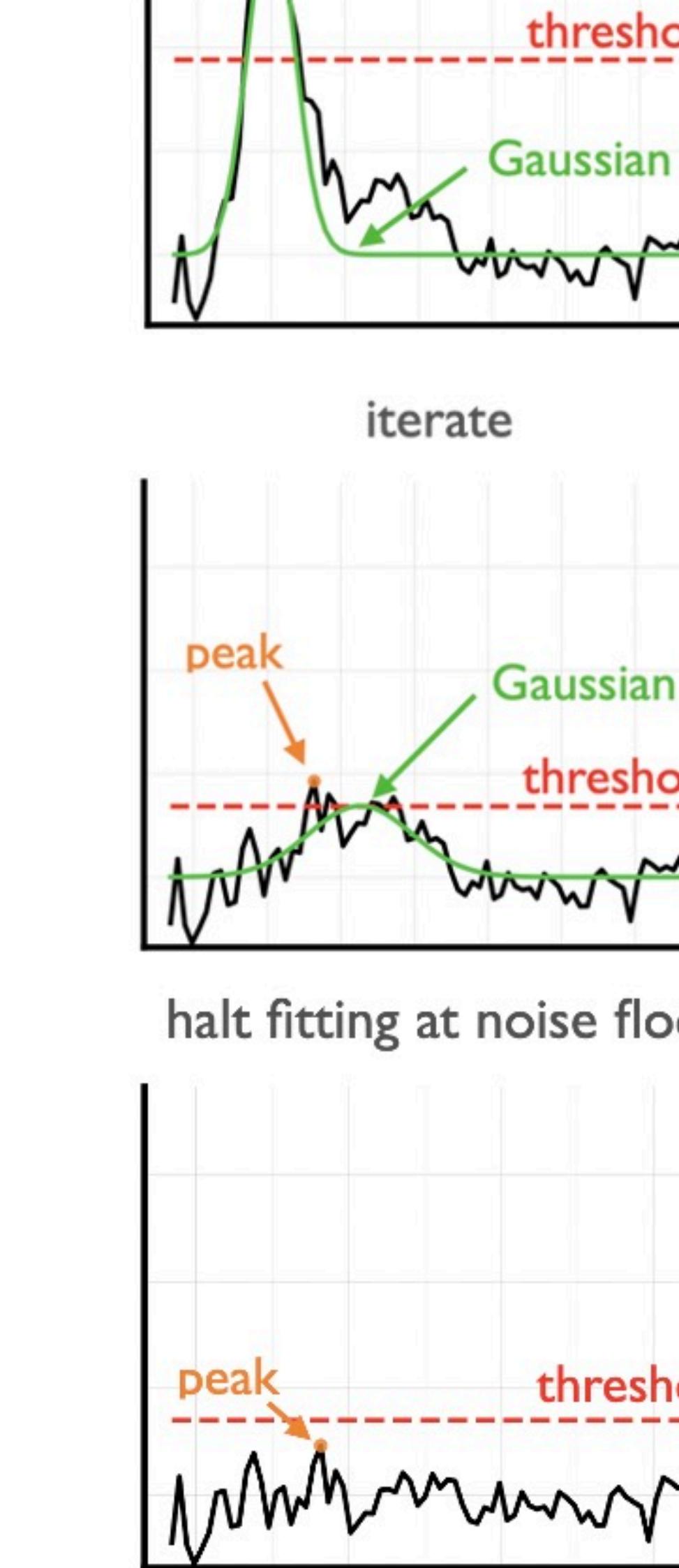
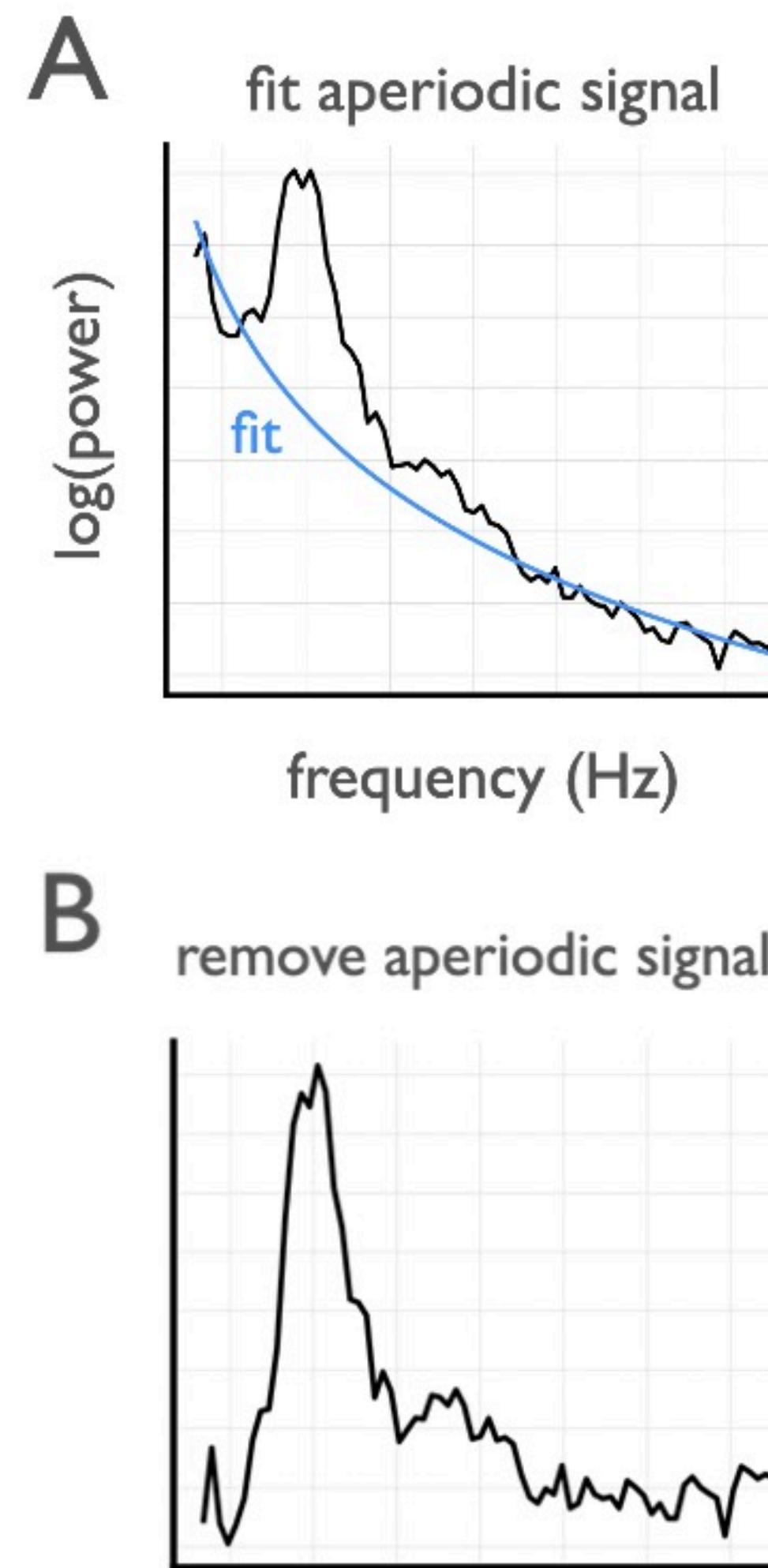
Luyanda Mdanda



Julio Dominguez

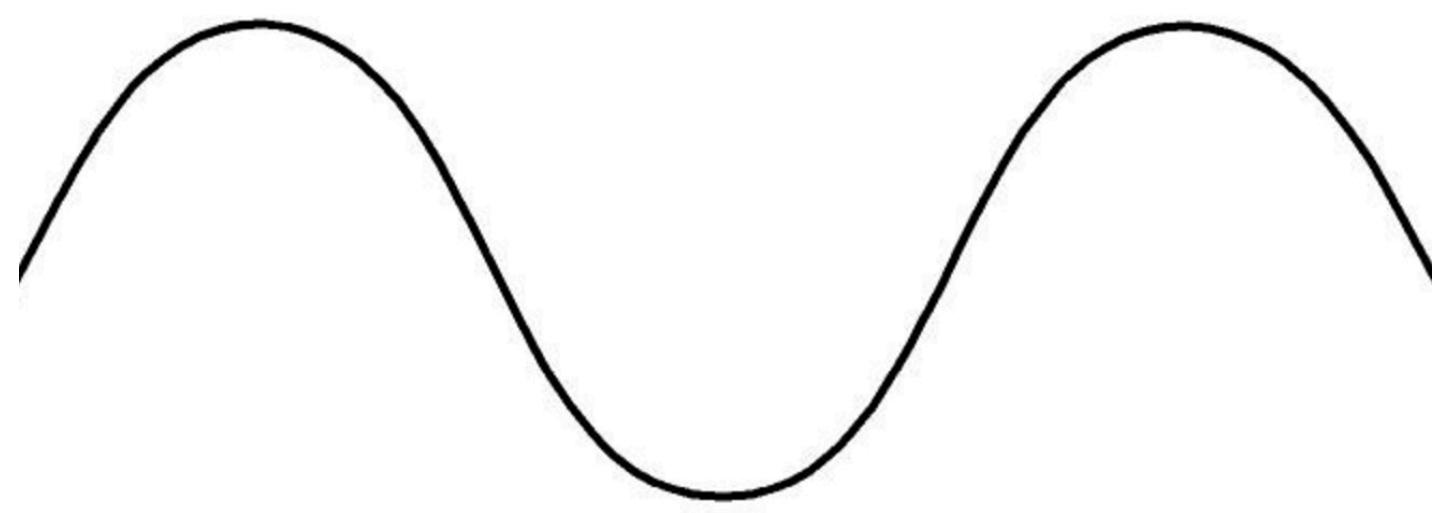


algorithm



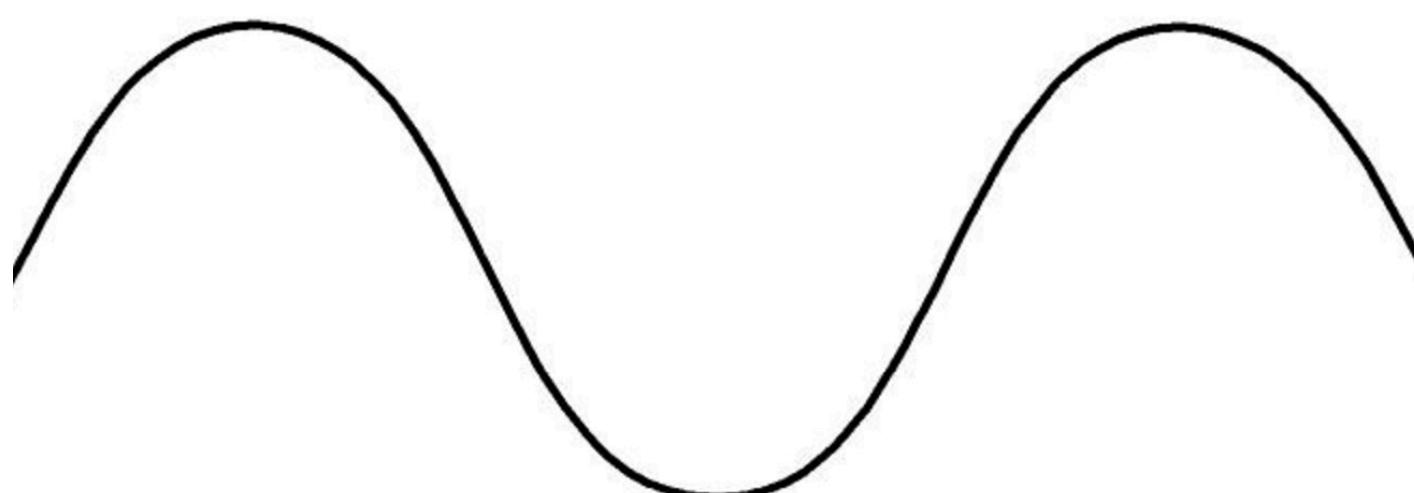
But wait, there's more!

sin

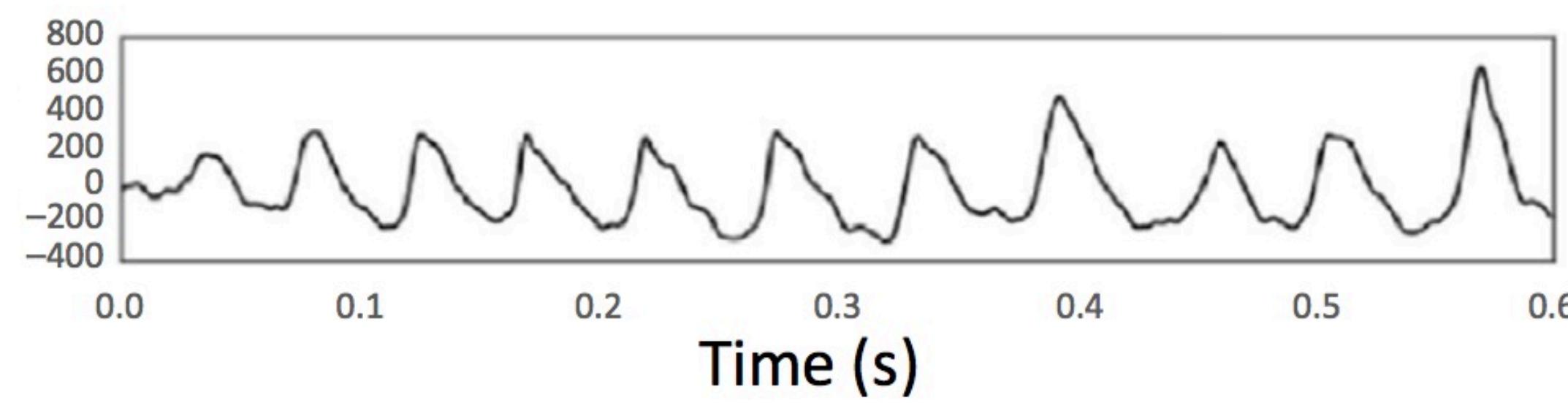


What's the problem?

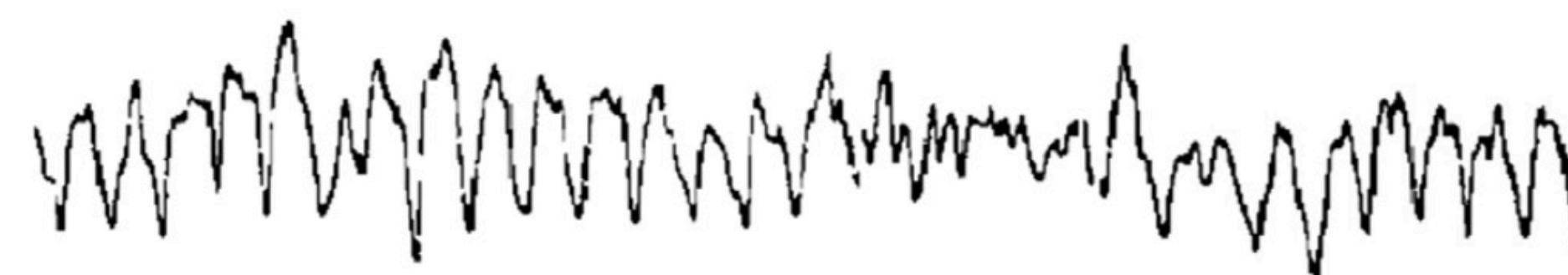
Neural oscillations are *not* sinusoidal



sinusoid

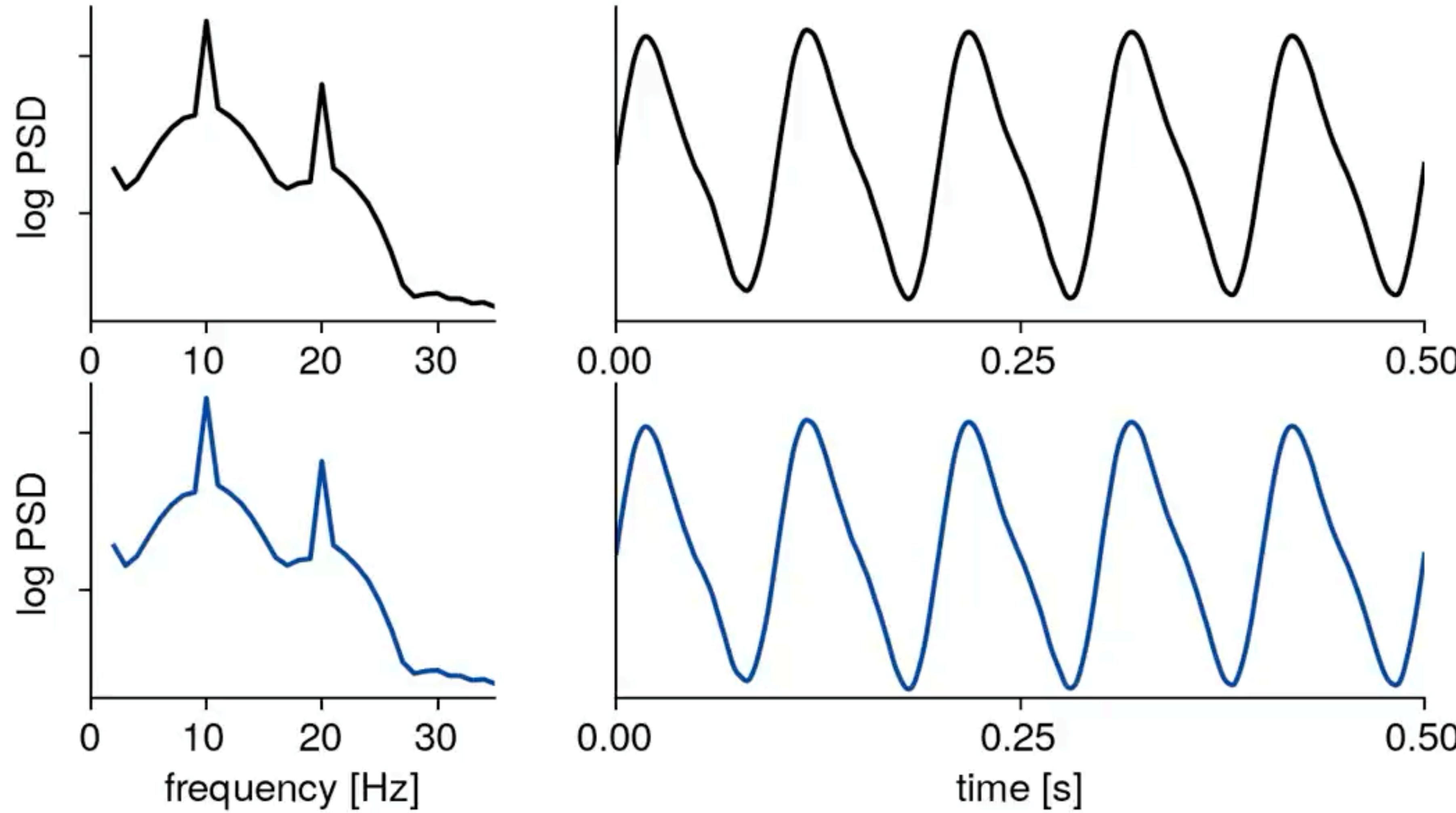


not sinusoids

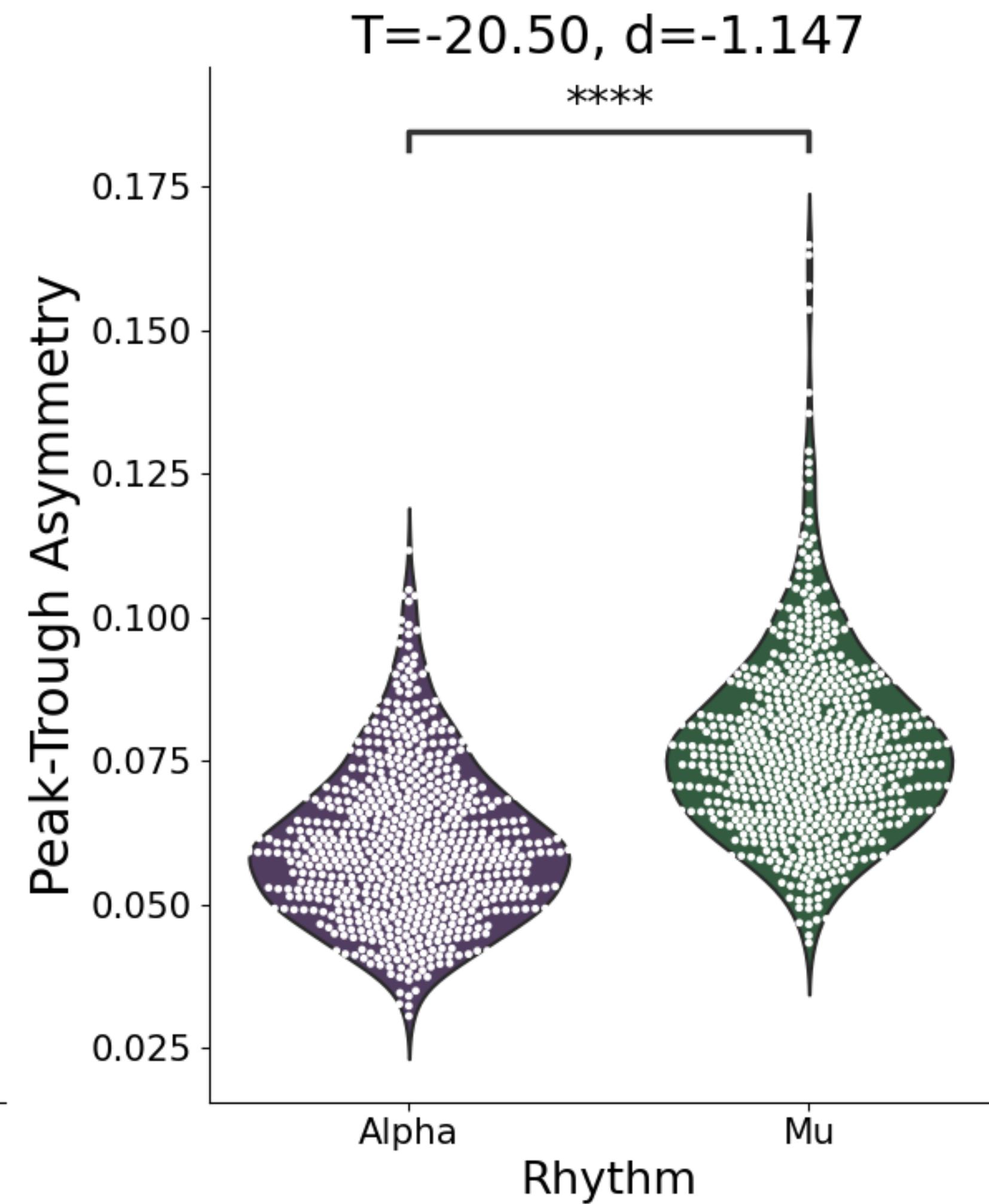
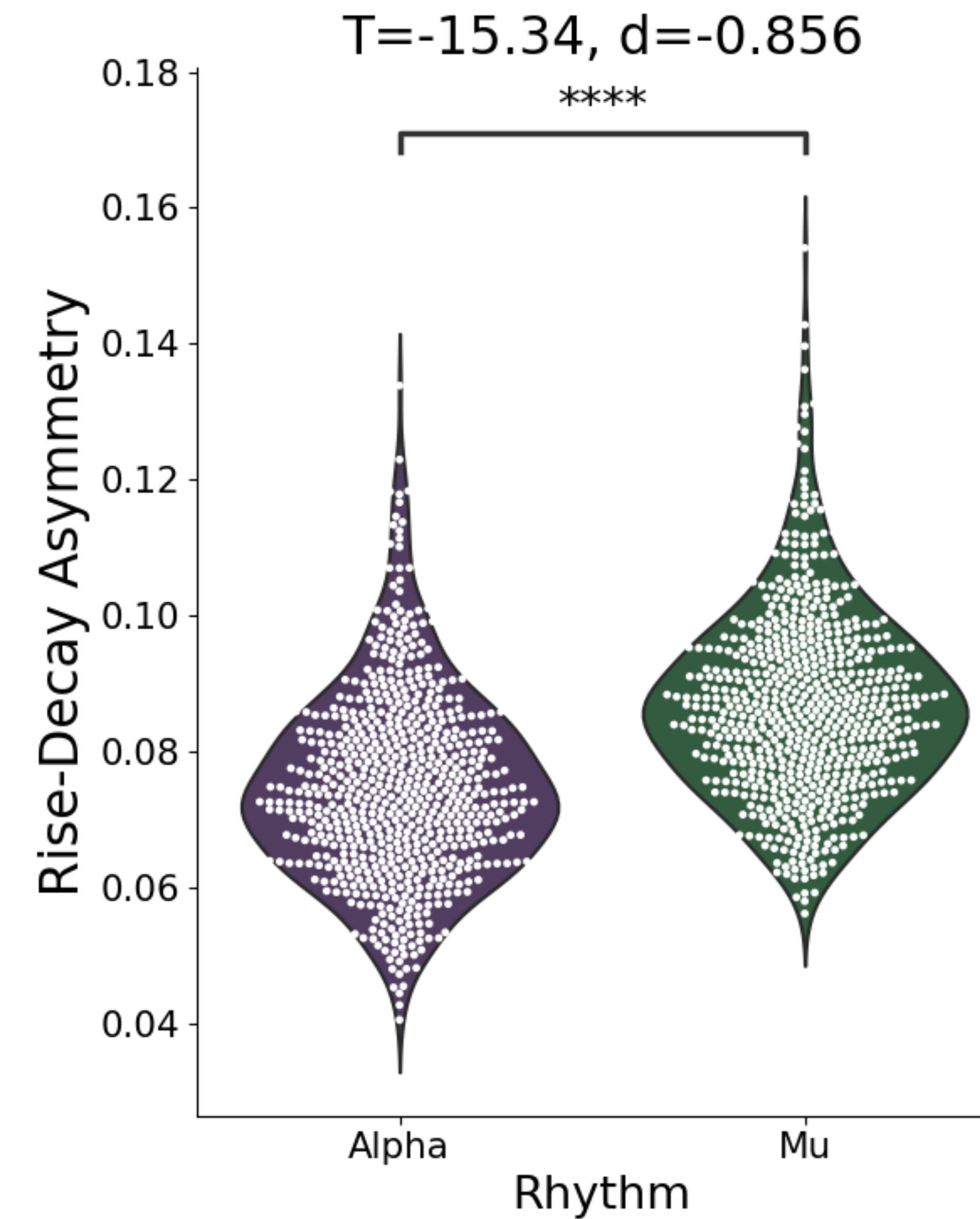


1 s

Nonsinusoidal harmonics



Alpha and mu

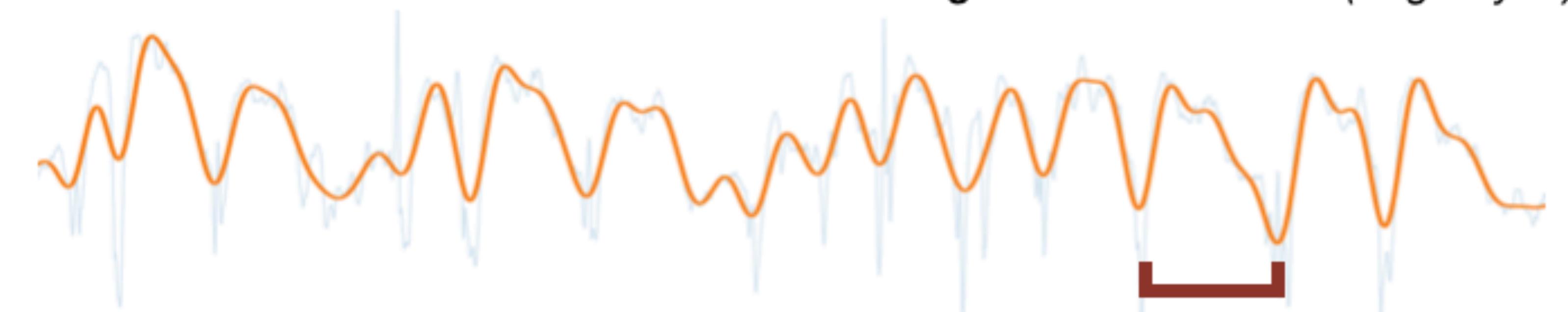
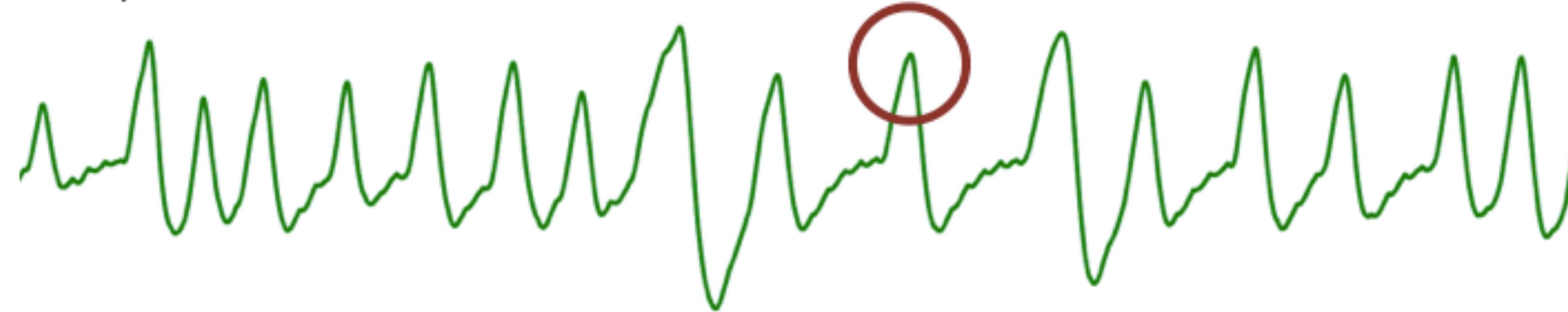


Andrew Bender



Respiration

— Raw iEEG
— Lowpass Filtered (<4Hz)
— Respiration



Eena Kosik



**We can't adjudicate between these
without careful parameterization**

What's a solution?

Python!

pip install

- neurodsp (Cole et al., *J Open Source Softw* 2019)
- bycycle (Cole & Voytek, *J Neurophysiol* 2019)

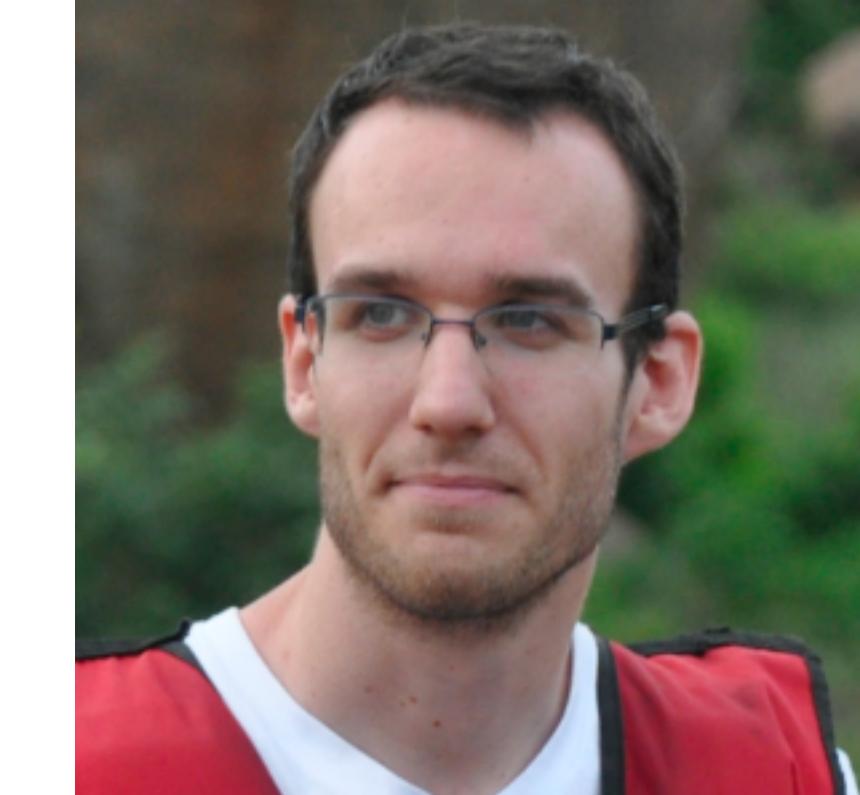
Andrew Bender



Ryan Hammonds



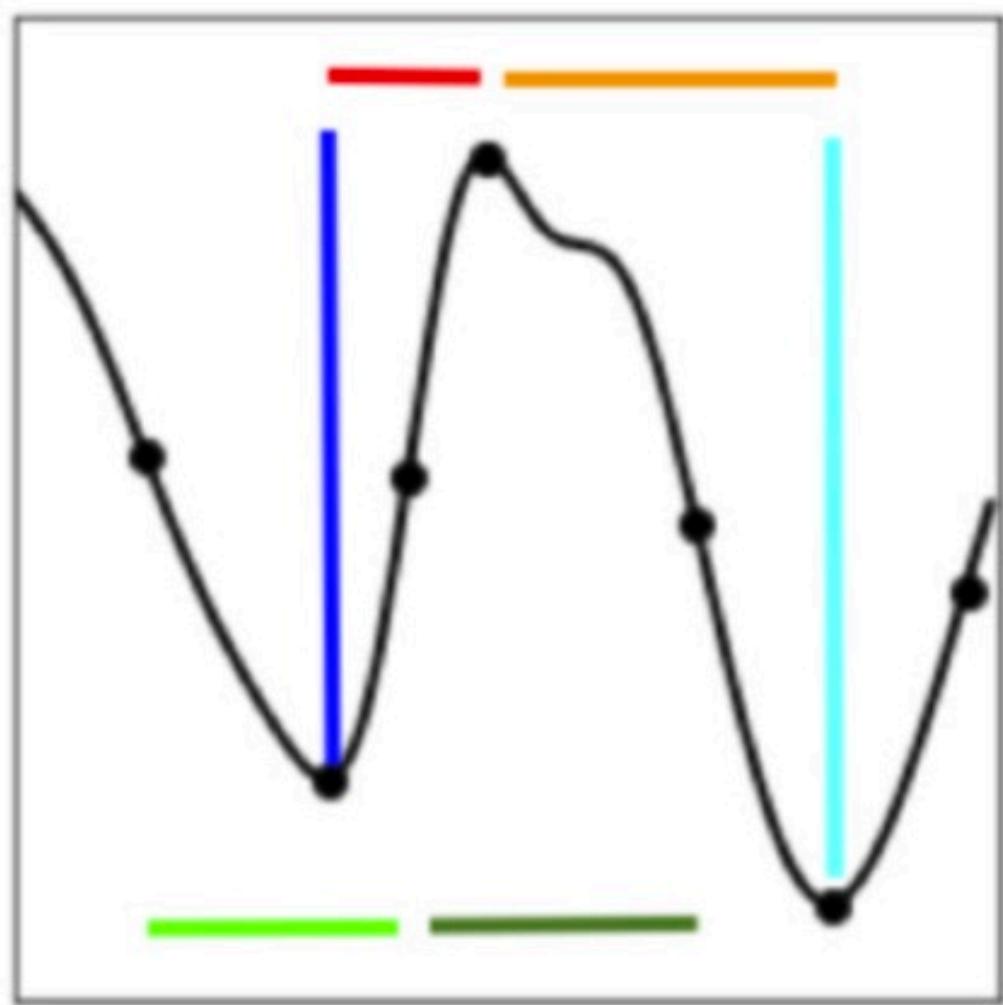
Scott Cole, Ph.D.



Natalie Schawronkow, Ph.D.



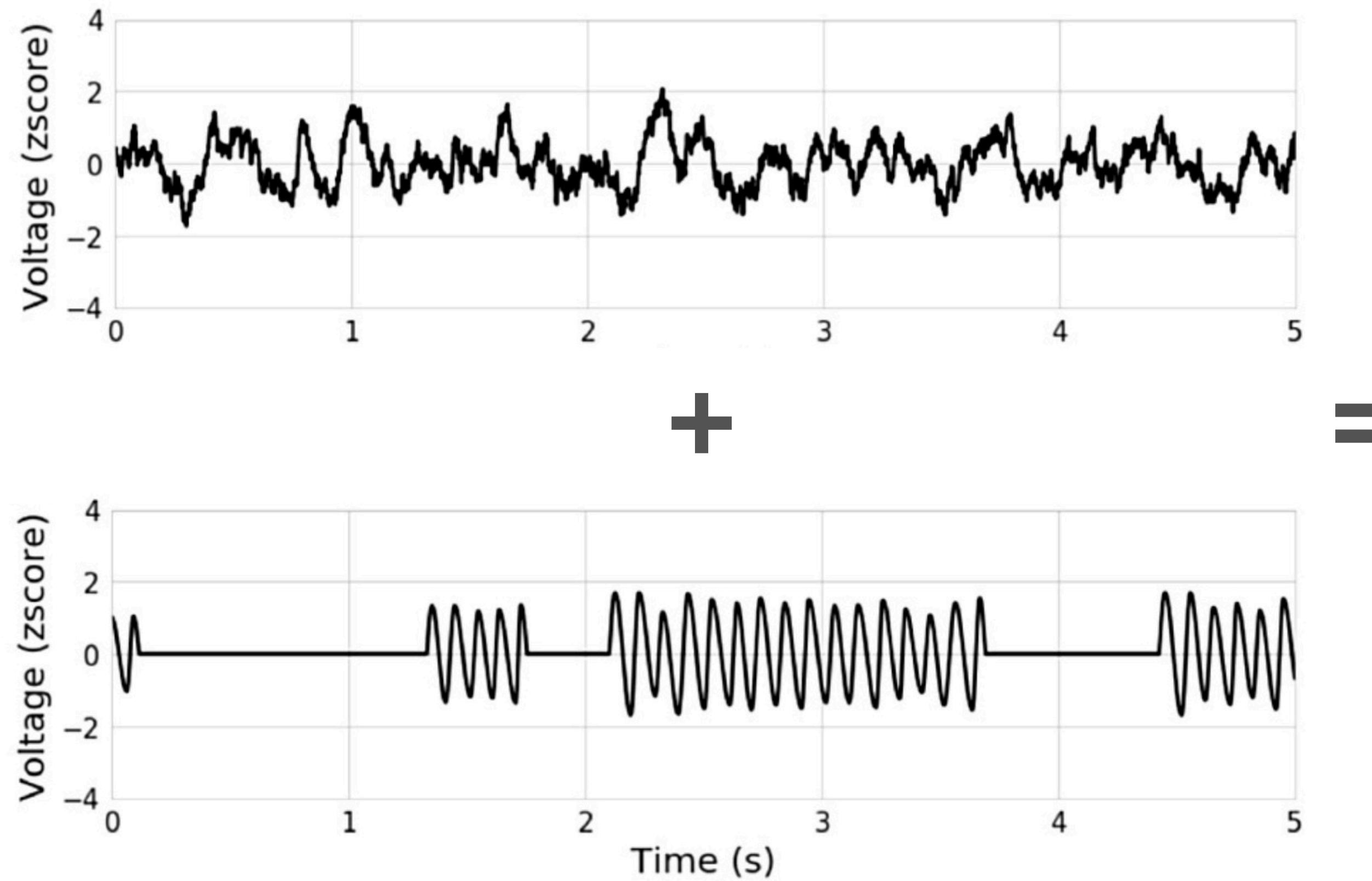
Bycycle!



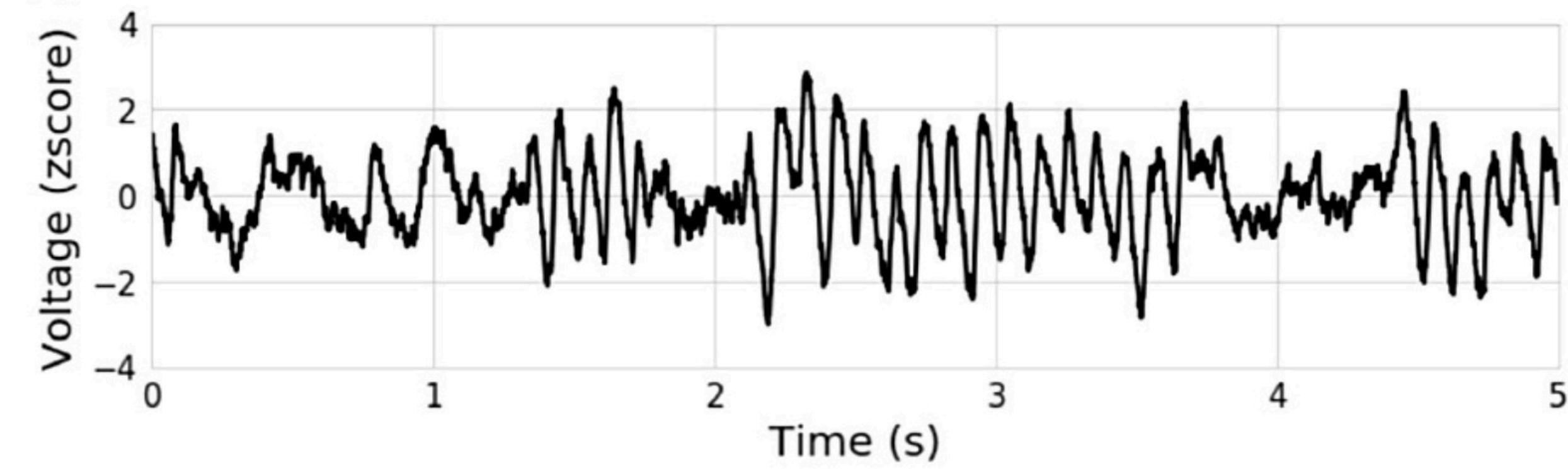
- Amplitude $= (\text{blue} + \text{cyan}) / 2$
Period $= \text{red} + \text{orange}$
Rise-decay symmetry $= \text{red} / (\text{red} + \text{orange})$
Peak-trough symmetry $= \text{green} / (\text{green} + \text{cyan})$

	Trough time	Amplitude	Period	rdsym	ptsym
	0.12	2.9	105	0.43	0.51
	0.21	1.7	89	0.34	0.5
	0.31	1.9	99	0.4	0.49
	0.4	2.2	82	0.32	0.52
	0.5	2.2	109	0.4	0.58
	0.61	2.2	108	0.44	0.57

Ground truth simulations



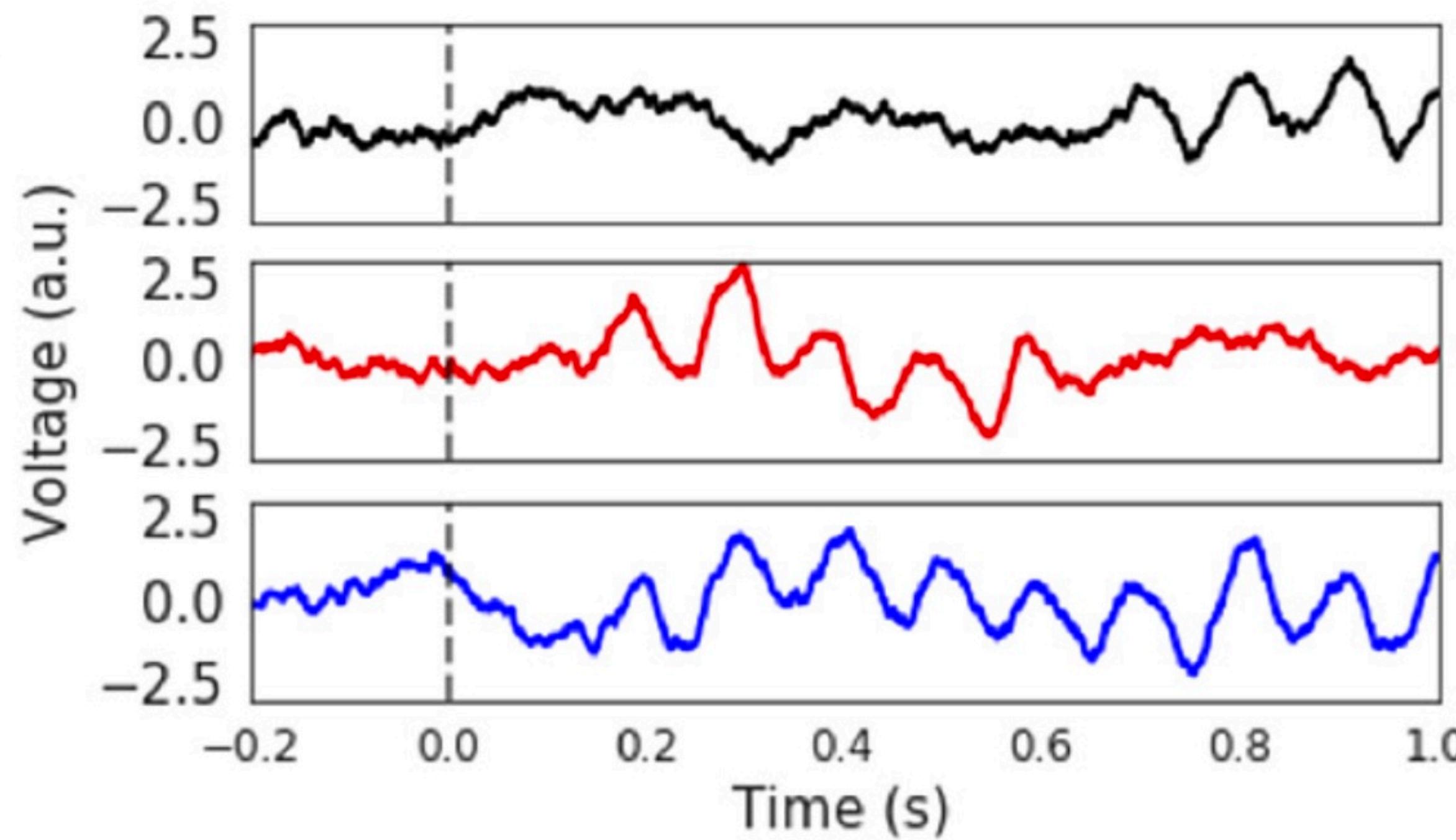
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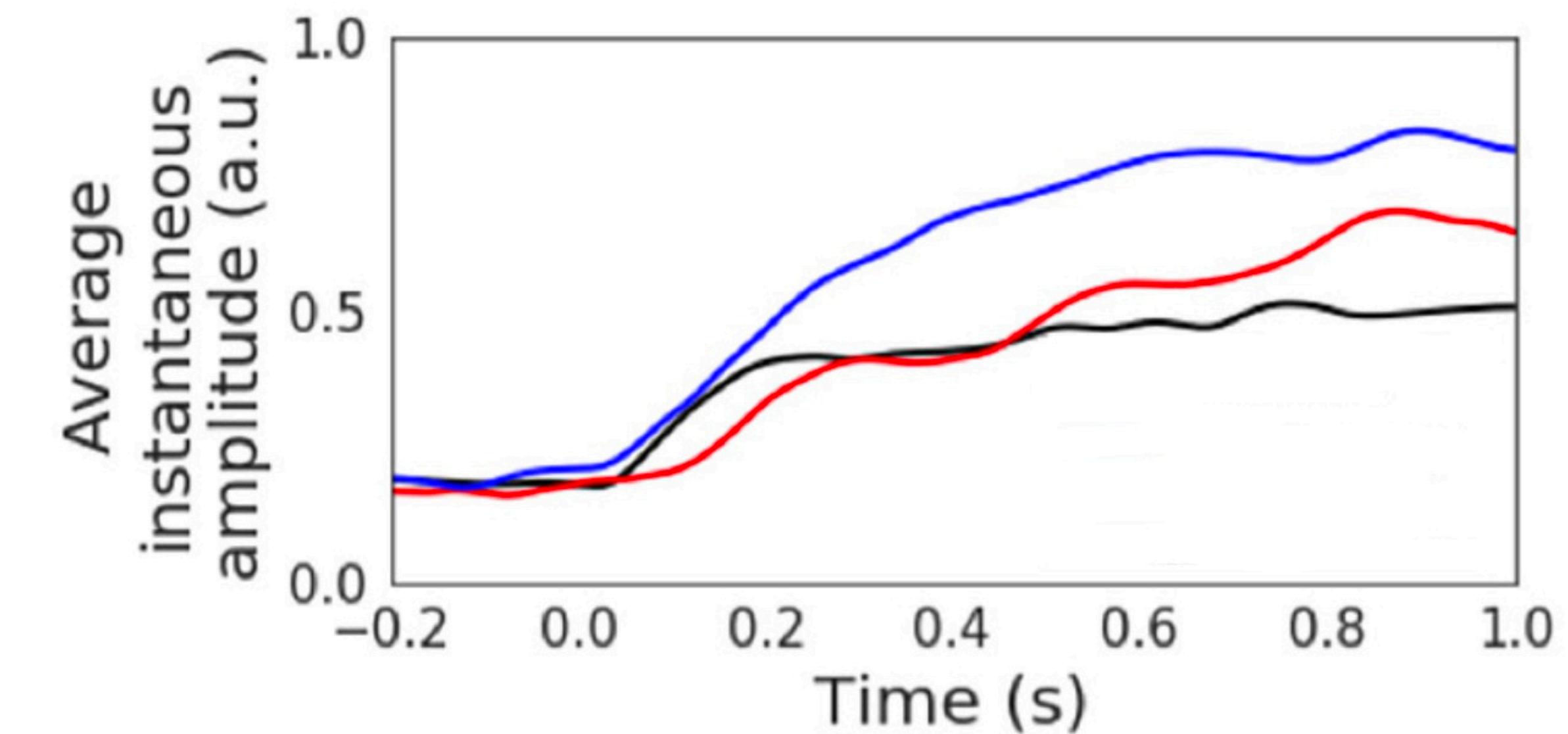
Event-related simulations

- baseline
- higher amp
- more bursts

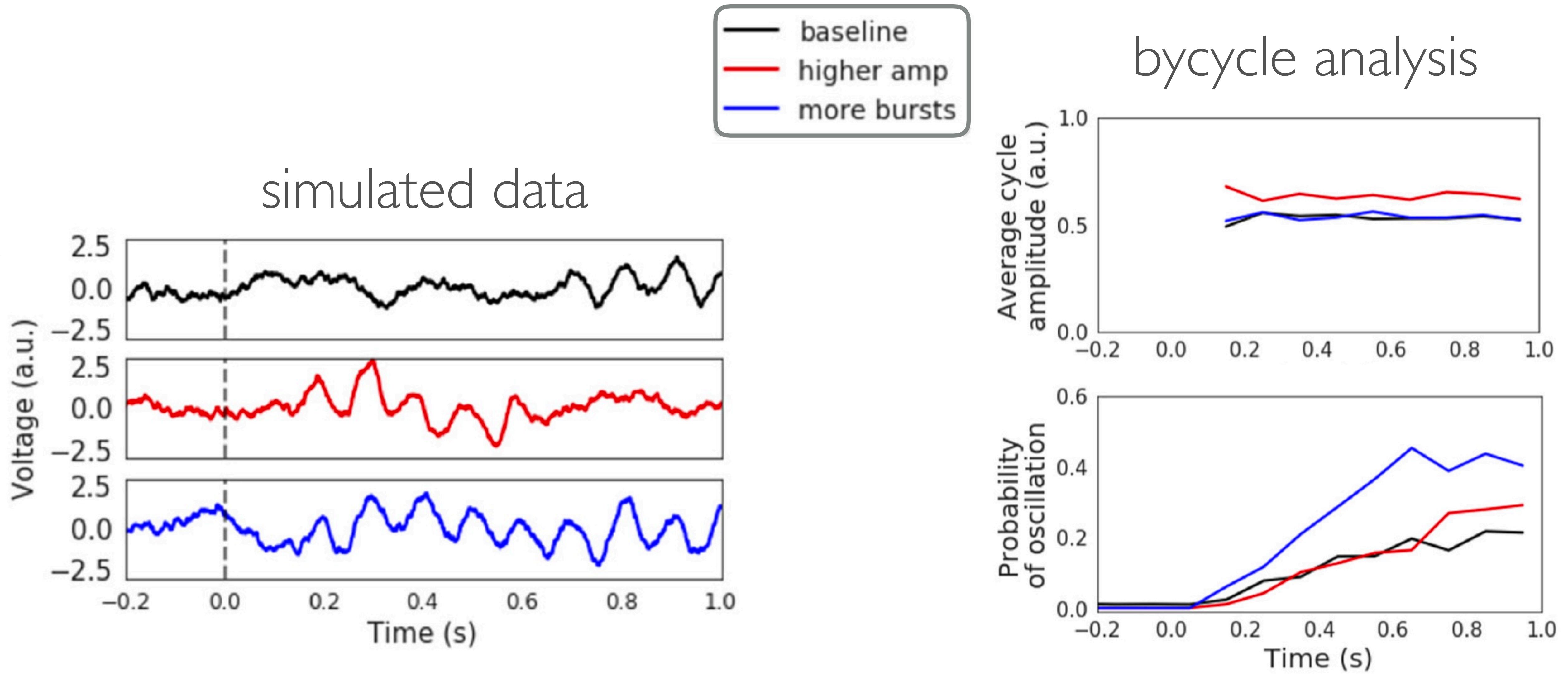
simulated data



traditional analysis

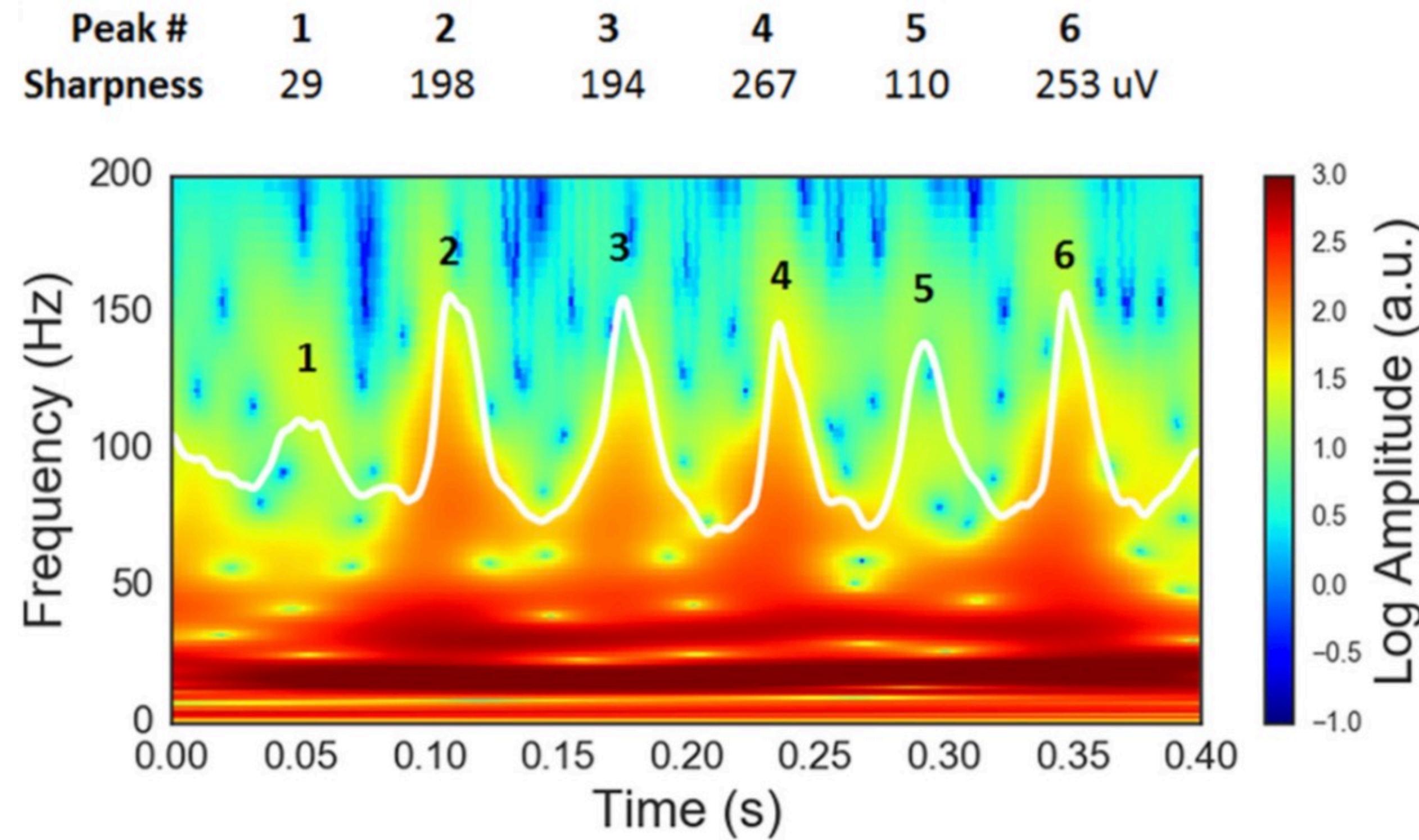


Event-related simulations

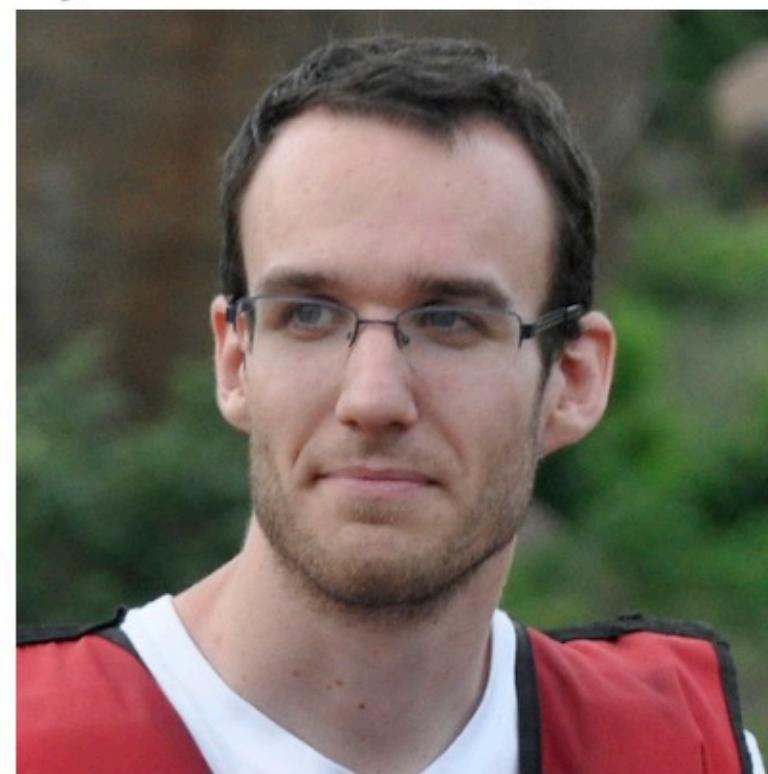


This matters

Nonsinusoidal waveforms in Parkinson's disease



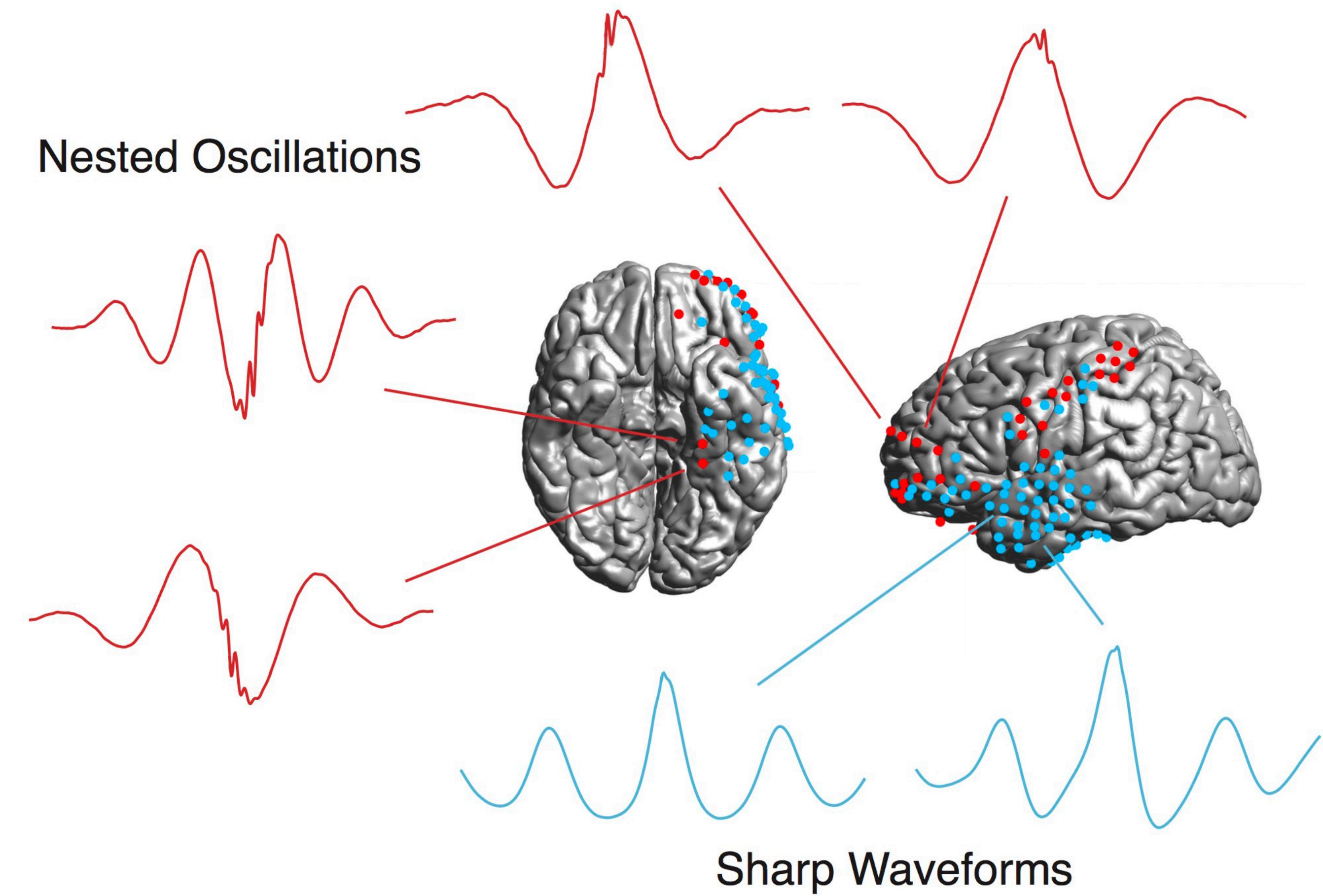
Scott Cole ([twitter](#), [web](#), [CV](#))
Formerly: PhD Student
Currently: Data Scientist, San Francisco



Postdoctoral
Researcher
Natalie Schawronkow



Not throwing the baby out!



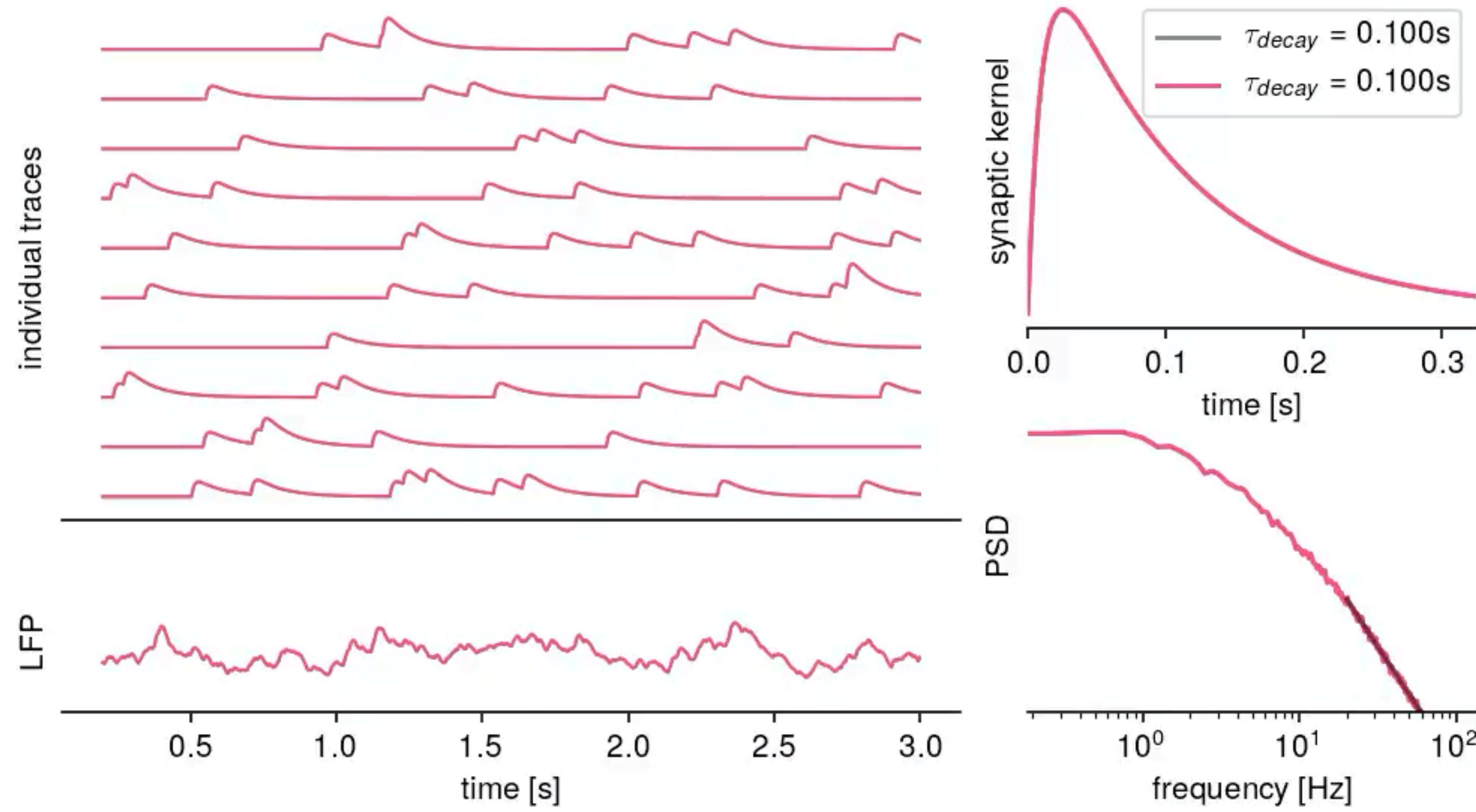
I/f detour

What is $1/f$ really?

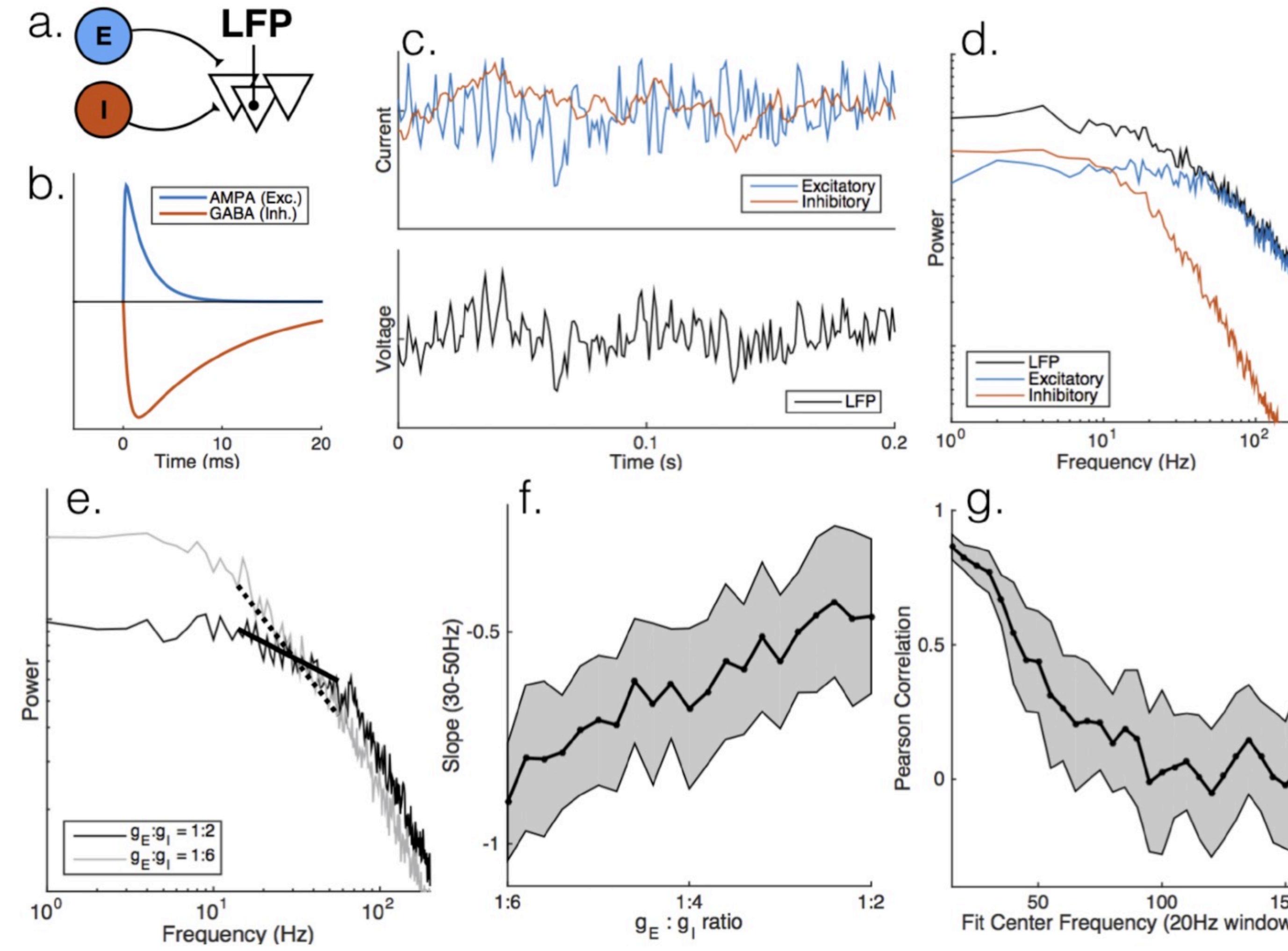
- Scale-free
- Self-organized criticality
- Fractality
- Long-term memory / long-range temporal correlation
- Power-law activity
- $1/f$ noise
- Aperiodic / arrhythmic

So what's the aperiodic signal?

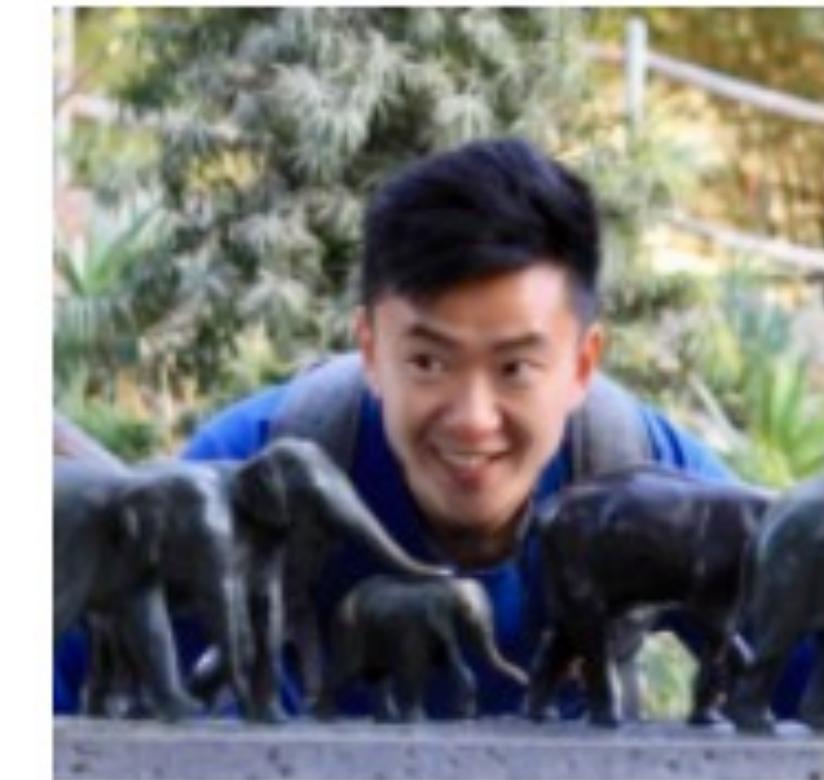
Origin of LFP / EEG



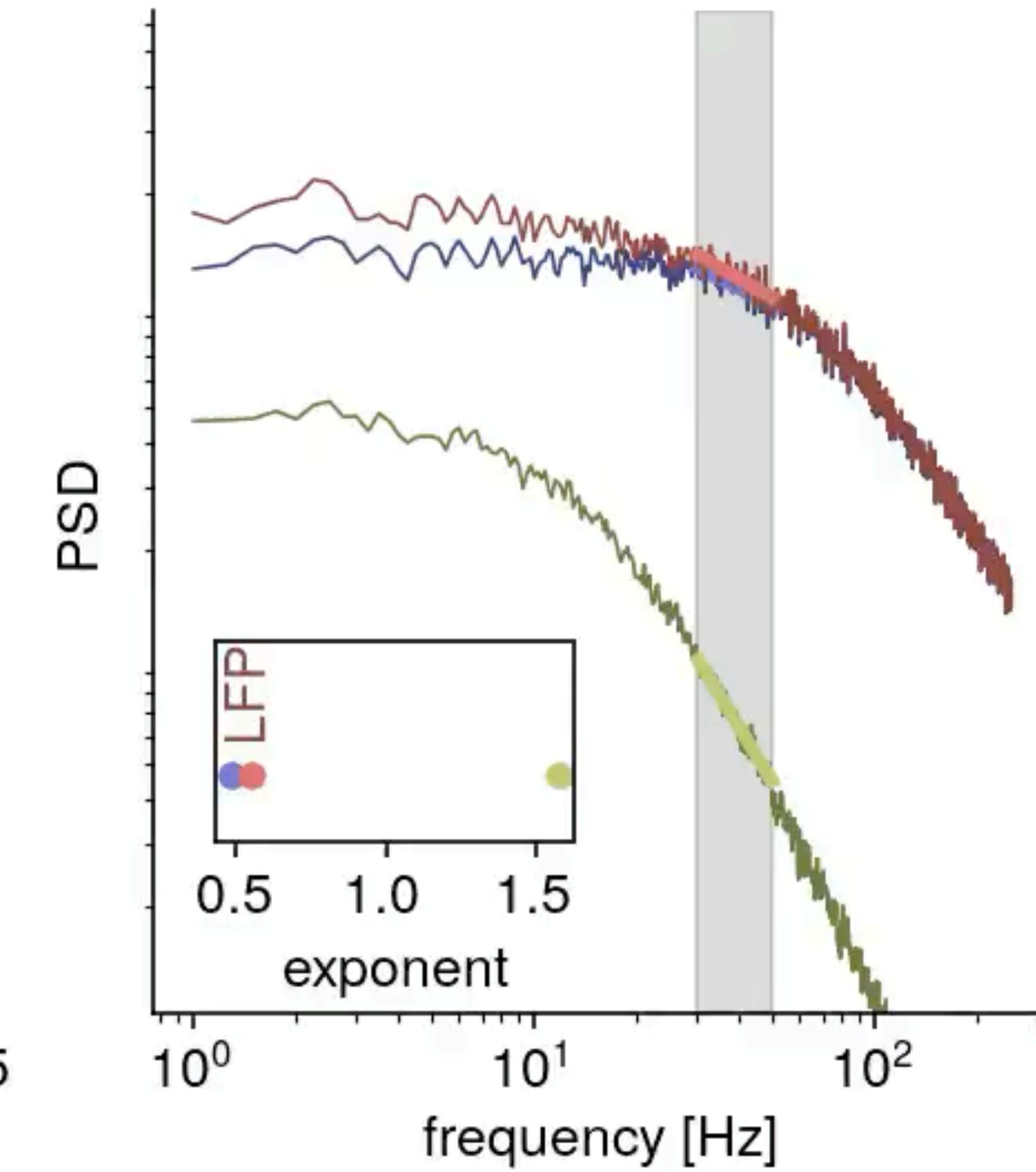
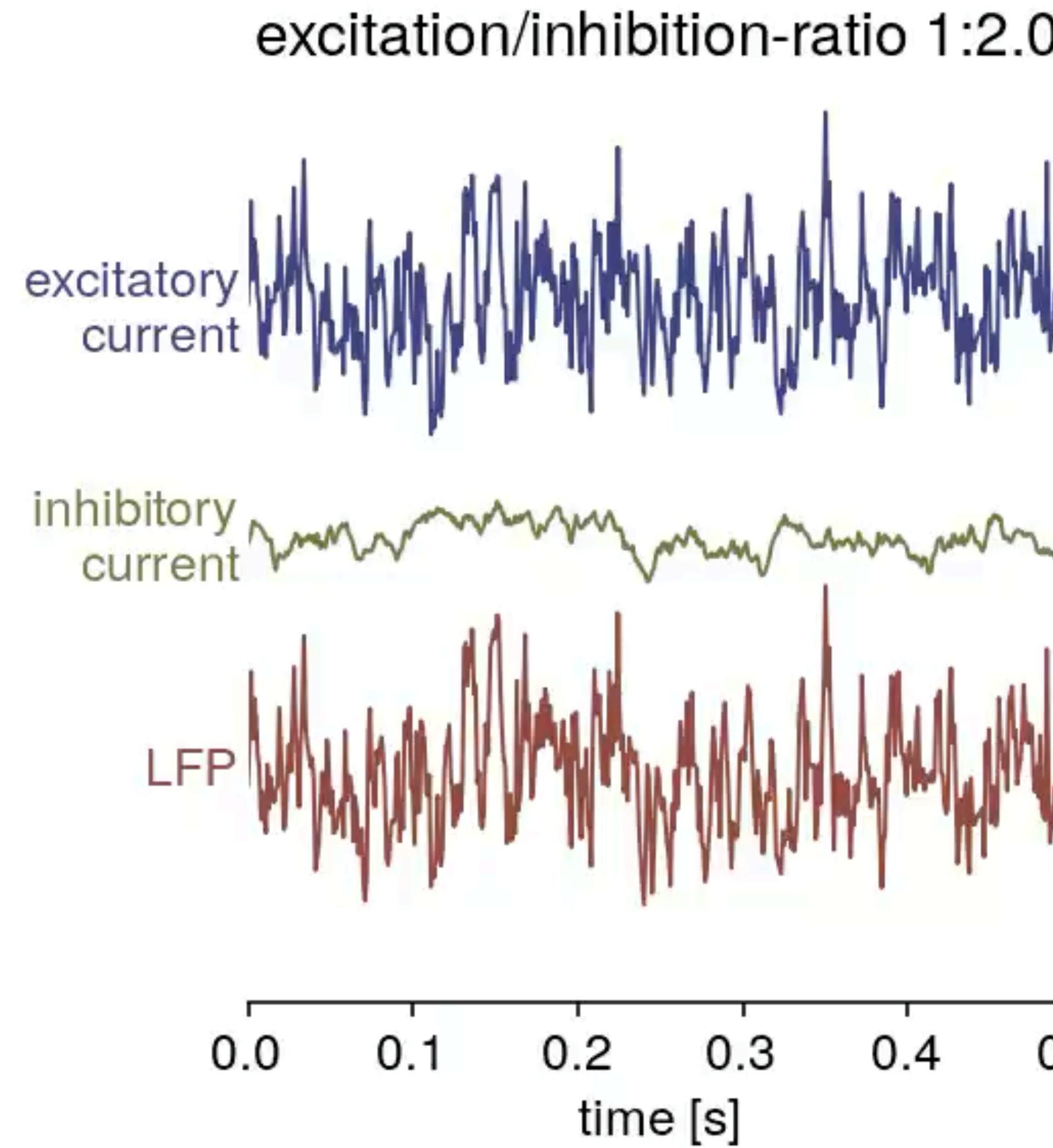
What does the aperiodic slope reflect?



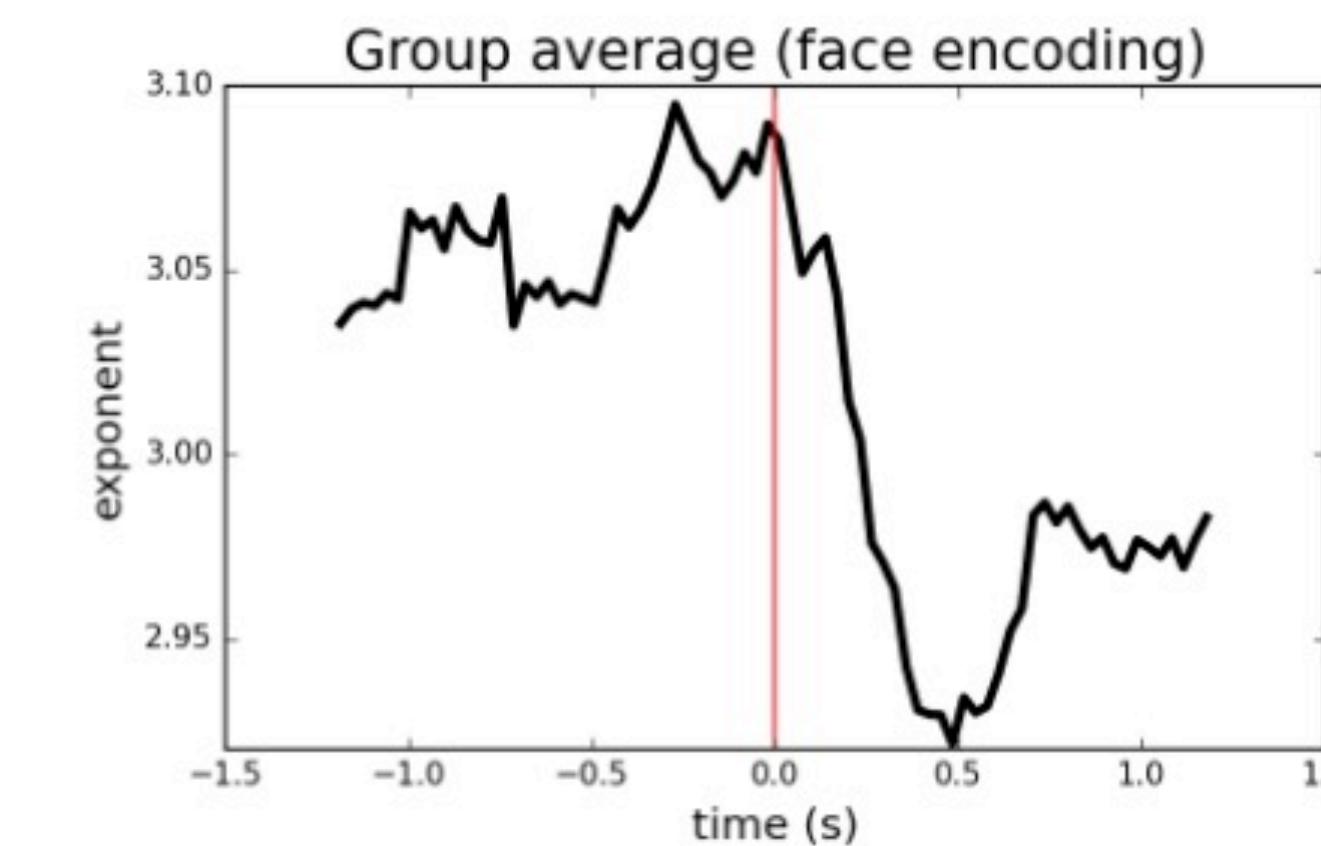
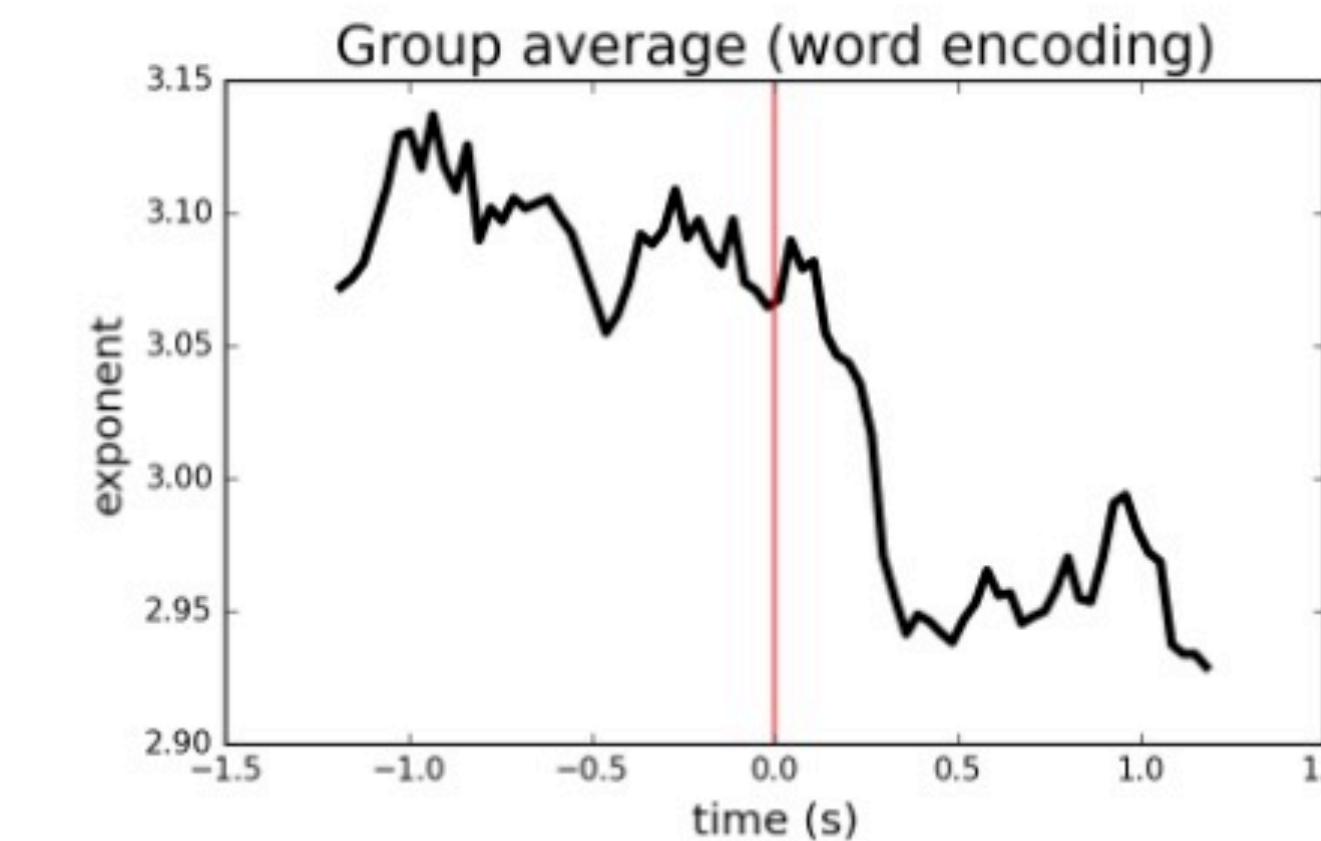
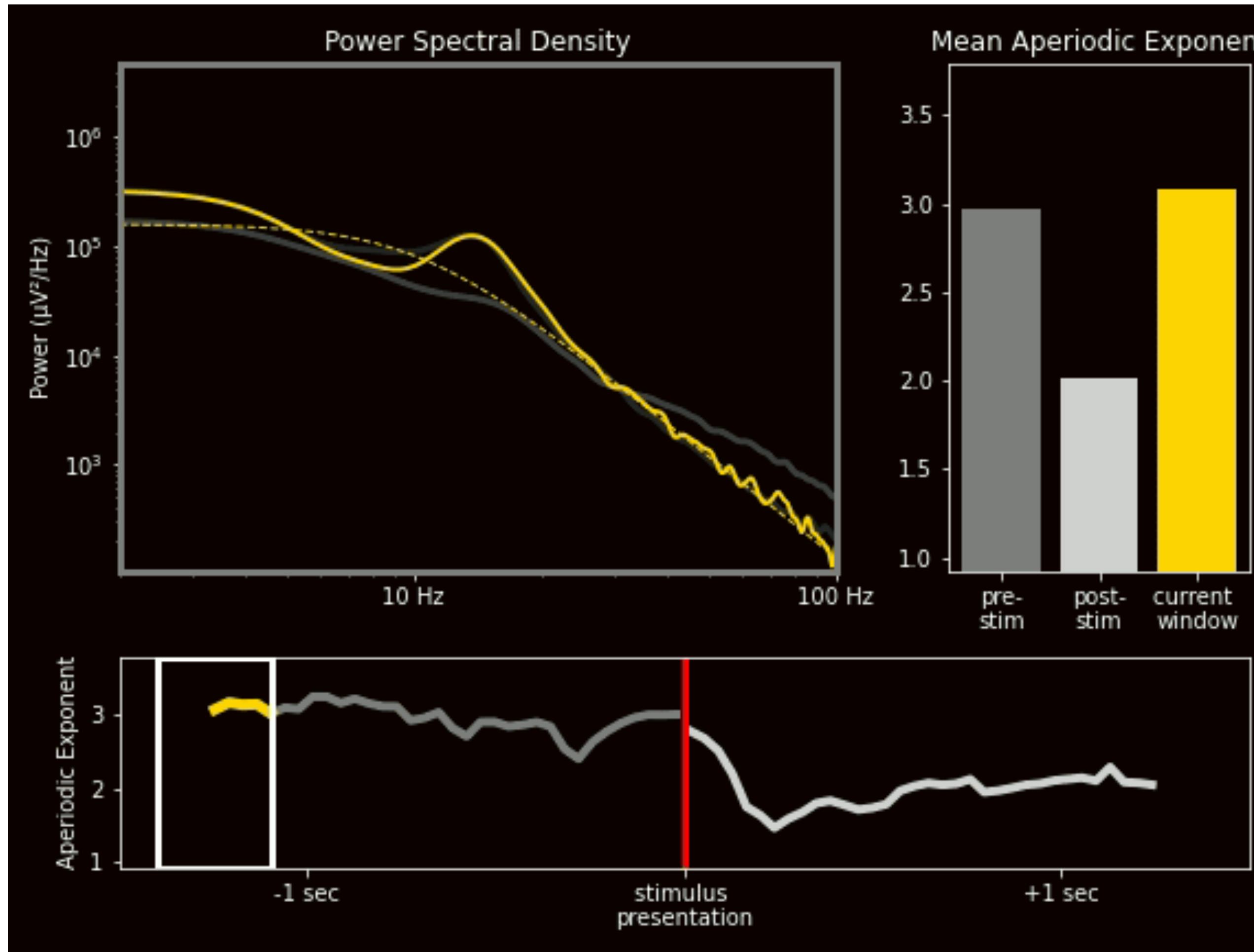
Richard Gao



El balance



Aperiodic activity is dynamic

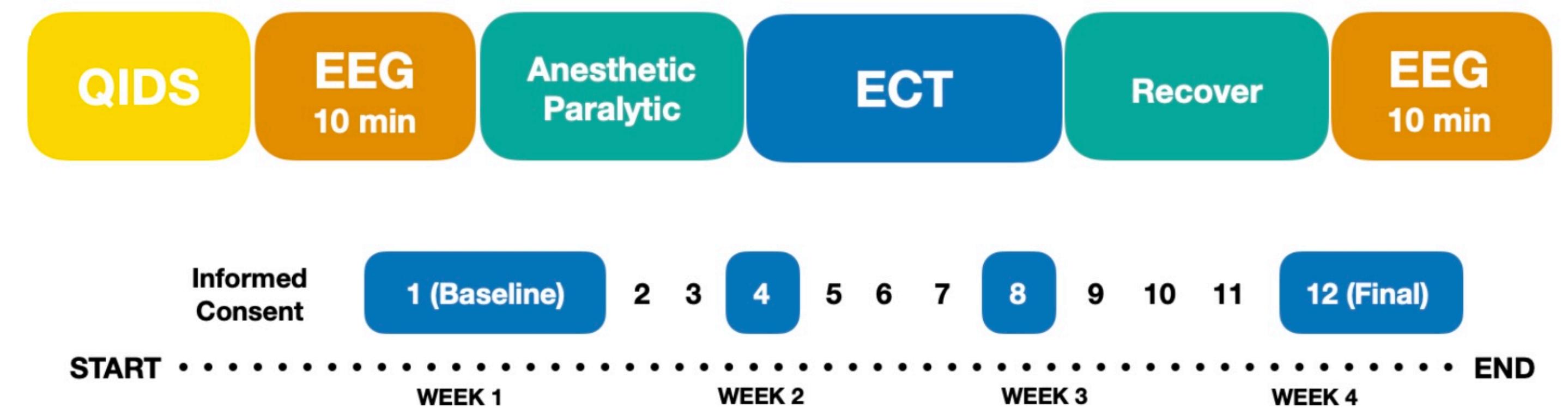


Michael (MJ) Preston



This matters

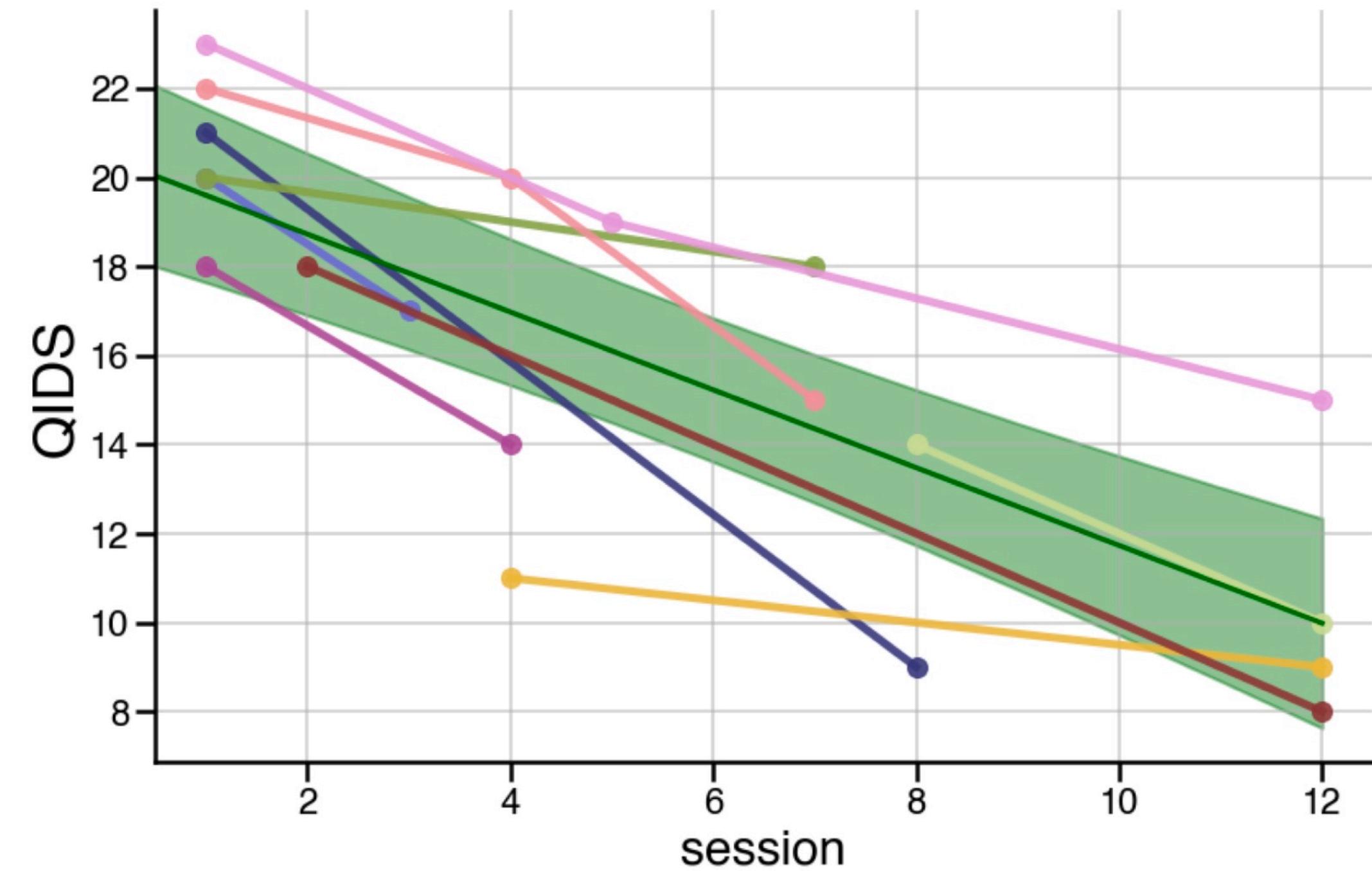
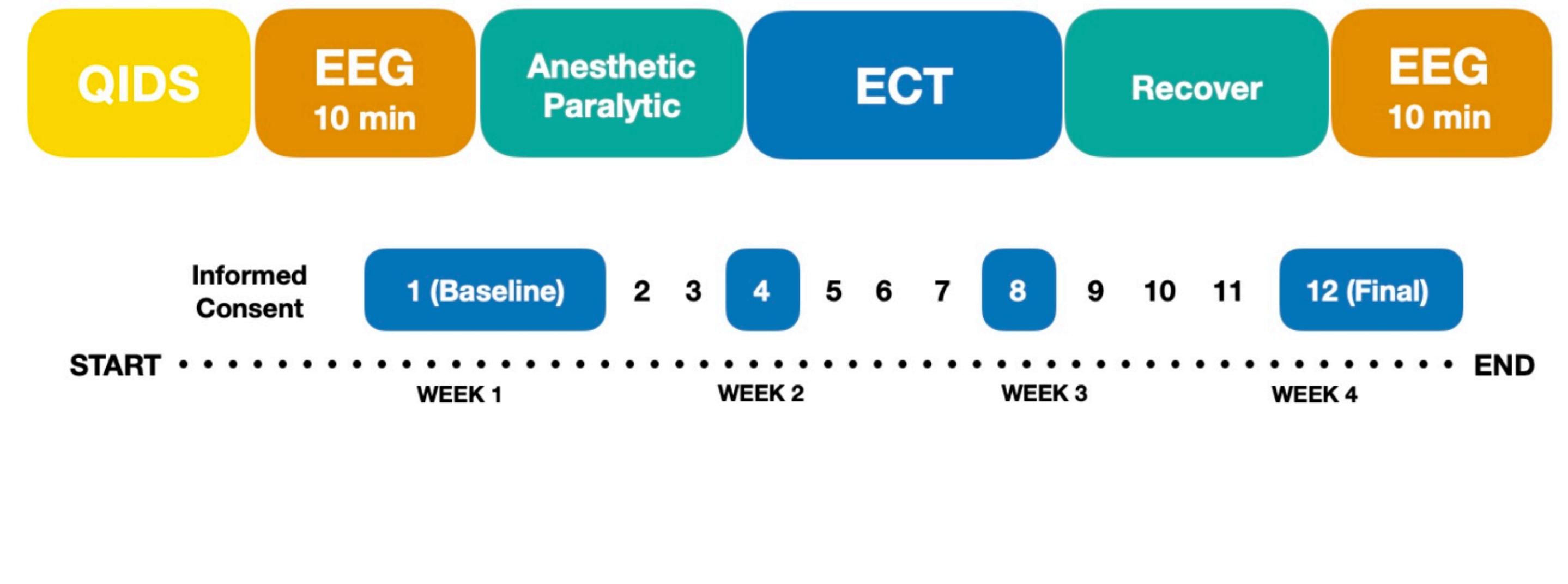
Aperiodic activity in major depressive disorder



Sydney Smith



Aperiodic activity in major depressive disorder



Aperiodic activity in major depressive disorder

