# DATA QUALITY

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@ UBA ECI Course
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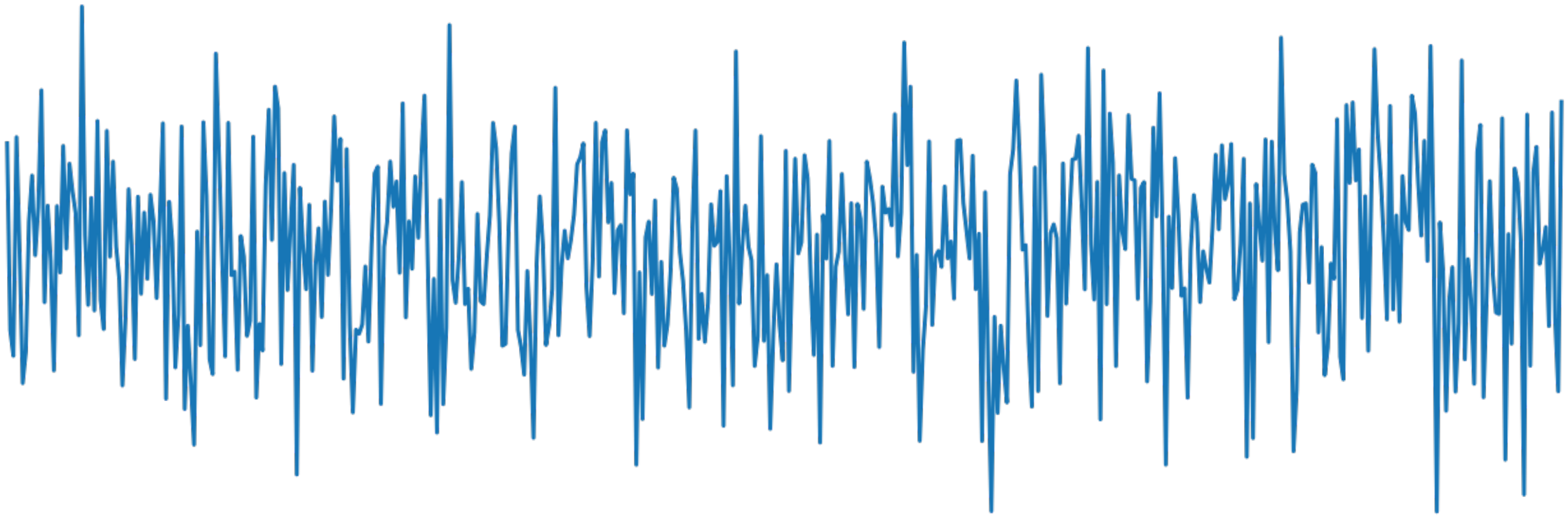
# ONLINE MATERIALS

http://github.com/alexhuth/eci-2017

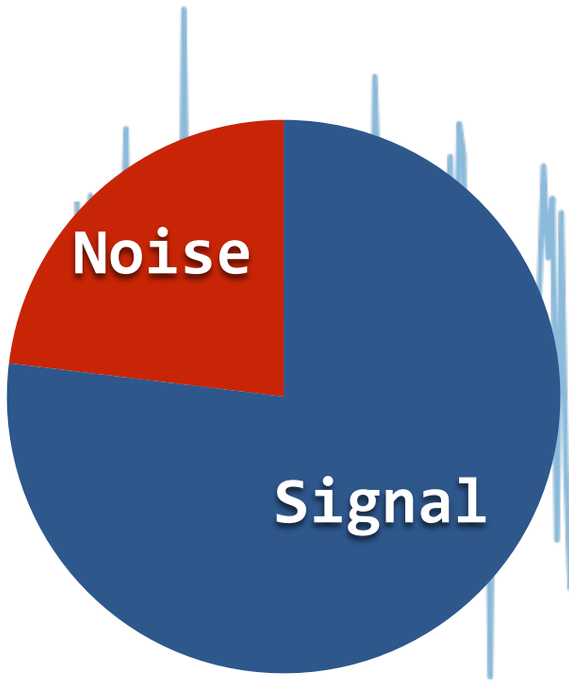
# BEFORE YOU DO ANYTHING ELSE,

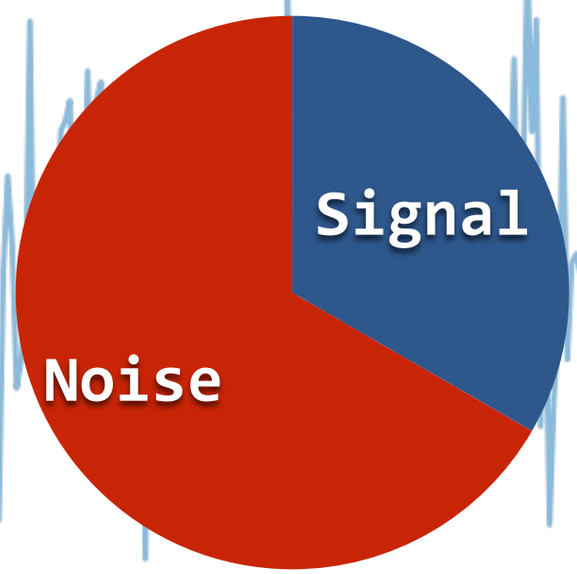
# *MAKE SURE YOUR DATA IS GOOD*

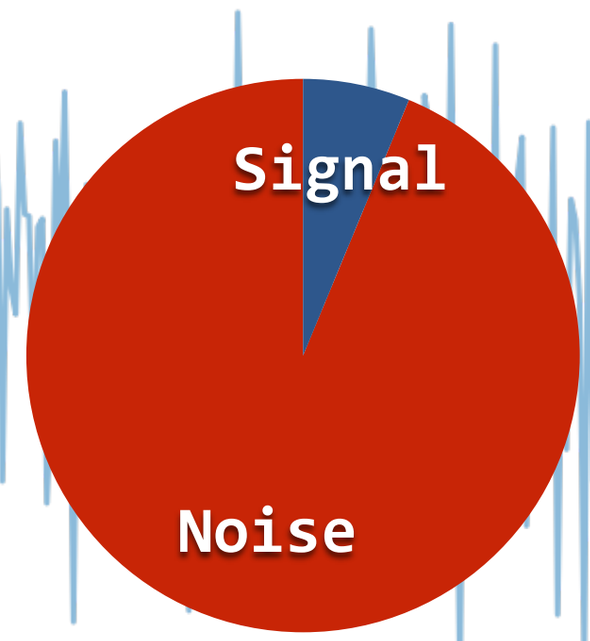
# HOW GOOD IS YOUR (TIMESERIES) DATA?



# HOW GOOD IS YOUR (TIMESERIES) DATA?



# WHAT IS NOISE?

- If the same stimulus is repeated, the **NOISE** is different while **SIGNAL** is the same

$$x_i(t) = s(t) + \epsilon_i(t)$$

*measured response on i'th repetition*

# WHAT IS NOISE?

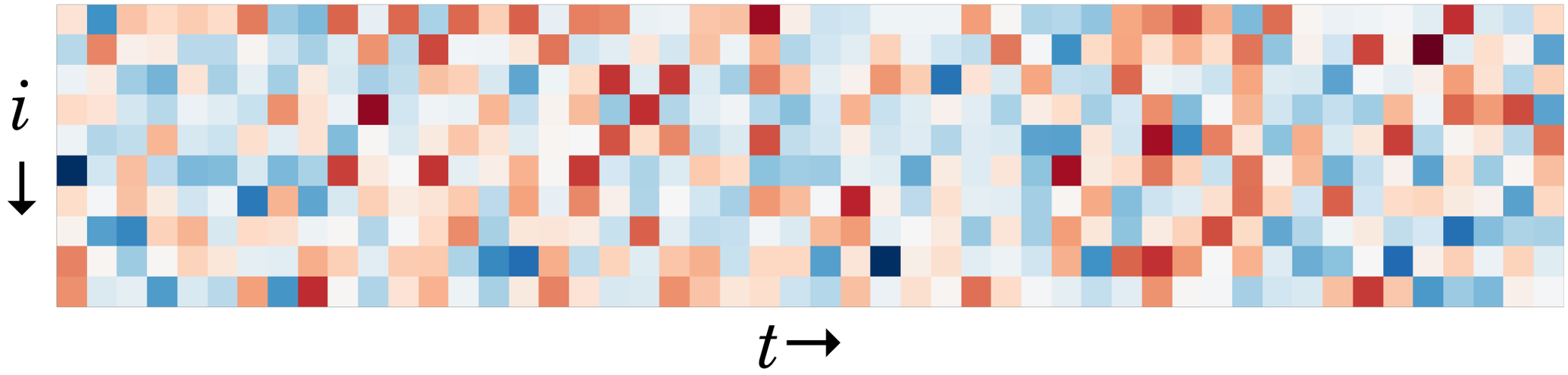
- (Assuming *stationarity* of the signal!)

# HOW DO WE KNOW?

- Repeat the same experiment multiple times
- The component of the response that is the same across repetitions is the **SIGNAL**, the components that are different are **NOISE**

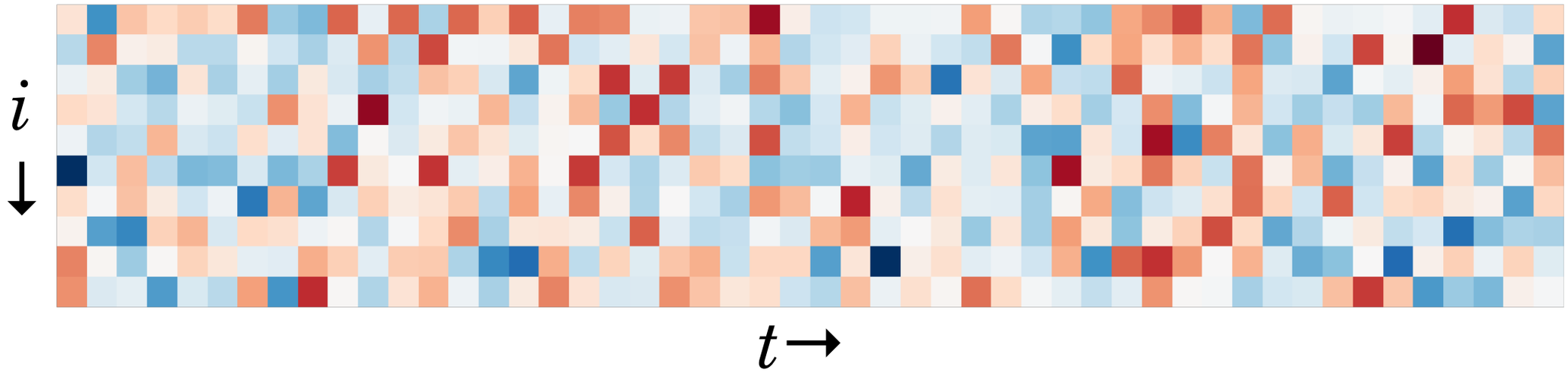
# HOW DO WE KNOW?

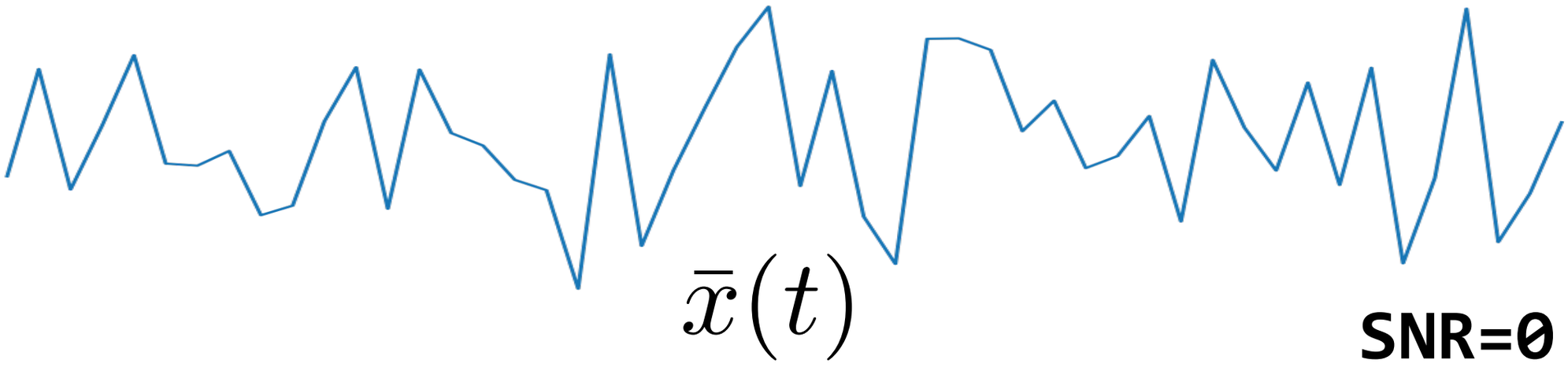
$$x_i(t)$$



# HOW DO WE KNOW?

$x_i(t)$

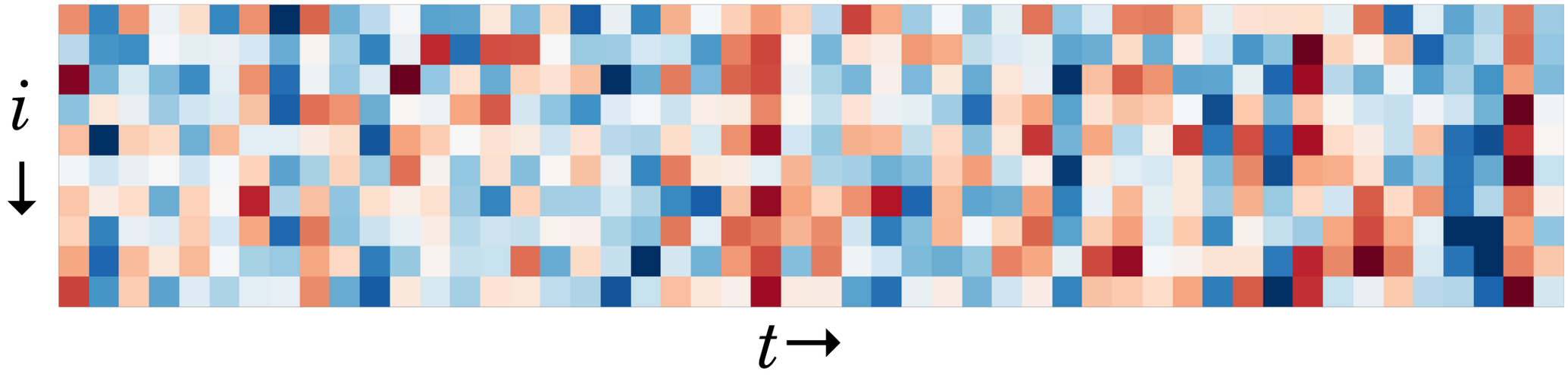


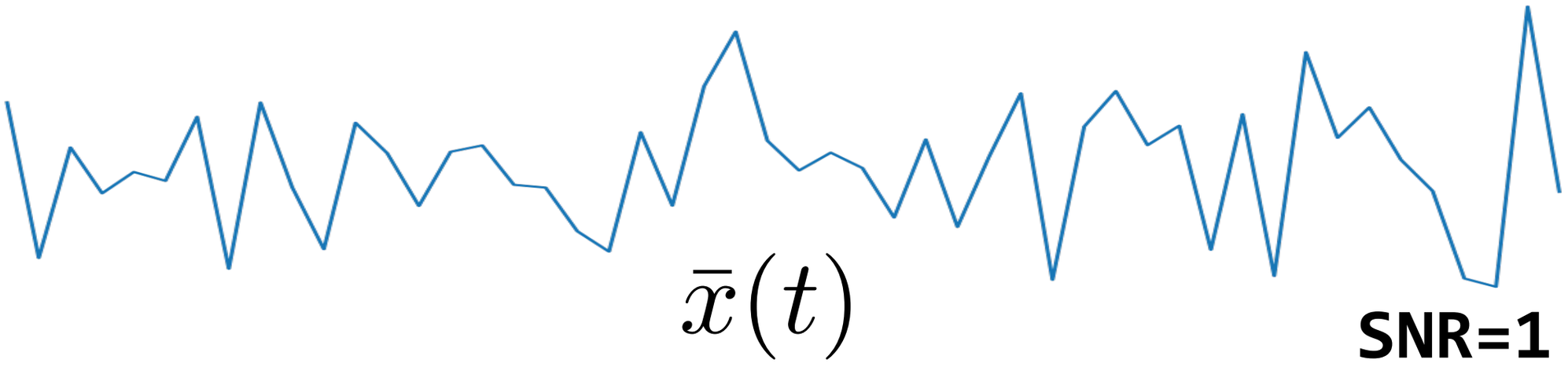




**SNR=0**

# HOW DO WE KNOW?

$x_i(t)$



# *PREGUNTA*

**What is noise? Is all trial-to-trial variability noise?**

- **Please:**
  - Think about this question for 2 minutes
  - Turn to your neighbor and discuss what you thought of

# METRICS FOR *REPEATABILITY*

- **SNR** (signal-to-noise ratio)
- **EV** (explainable variance)
- **MPWC** (mean pairwise correlation)
- **Coherence spectrum**

# SIGNAL TO NOISE RATIO

- The signal-to-noise ratio (**SNR**) is defined as:

$$SNR = \frac{\mathrm{var}(s(t))}{\mathrm{var}(\epsilon(t))}$$

- But this is rarely used in practice (at least for neuroscience data)

# SIGNAL TO NOISE RATIO

- In practice **SNR** must be computed using mean response:

$$\hat{SNR} = \frac{\mathrm{var}(\bar{x}(t))}{\langle \mathrm{var}(x_i(t) - \bar{x}(t)) \rangle_i}$$

# SIGNAL TO NOISE RATIO

- **NB:** *Functional* **SNR** is *not* **tSNR** (temporal SNR) aka **SFNR** (signal to fluctuation noise ratio) commonly used in MRI & image processing

- **tSNR/SFNR** are usually defined as inverse of coefficient of variation:

$$tSNR = \frac{\text{mean}(x(t))}{\text{std}(x(t))}$$

# EV
# (EXPLAINABLE VAR.)

- How much of the total variance is explained by the mean across repeats?

$$EV = 1 - \frac{\sum_i \mathrm{var}(x_i(t) - \bar{x}(t))}{\sum_i \mathrm{var}(x_i(t))}$$

# EV
# (EXPLAINABLE VAR.)

- EV is between 0 and 1 *(nice!)*
- EV is related to noise ceiling (later!)

# EV (EXPLAINABLE VAR.)

- **EV** is positive even for completely random datasets!
  - **EV** is biased upwards!
- Bias correction: $EV^* = EV - \frac{1 - EV}{N - 1}$

*number of repetitions*

# MPWC
# (MEAN PAIRWISE CORR.)

- On average, how correlated are the responses from different repeats with each other?

$$MPWC = \langle \mathrm{corr}(x_i(t), x_j(t)) \rangle_{i,j}$$

# MPWC (MEAN PAIRWISE CORR.)

- **MPWC** is easy to explain!
- **MPWC** is unbiased
- **MPWC** is almost identical to bias-corrected EV (proof left as exercise…)

# COHERENCE SPECTRUM

- First, **coherence** between two signals

*cross-spectral density*

$$C_{xy}(f) = \frac{|G_{xy}(f)|^2}{G_{xx}(f)G_{yy}(f)}$$

*autospectral density*

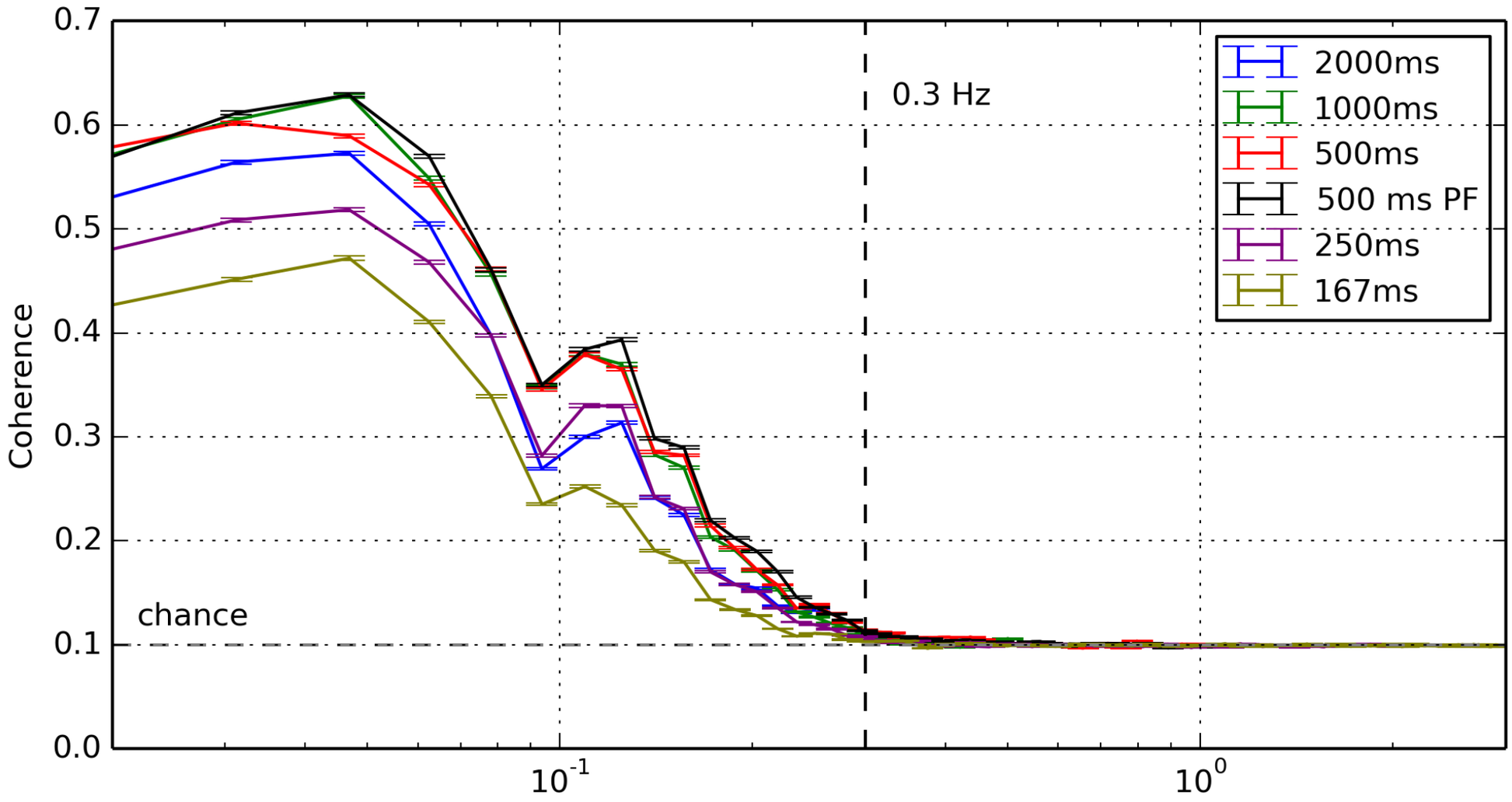
# COHERENCE SPECTRUM

- When used to measure data quality, **coherence** gives repeatability at each frequency!

$$Coh(f) = \langle C_{\bar{x},x_i}(f) \rangle_i$$

# COHERENCE SPECTRUM

**Example:** fMRI data collected at different sampling rates




*h/t James Gao, Anwar Nuñez*

# 10 MINUTE BREAK

# WHY IS REPEATABILITY IMPORTANT?

- Models require signal - test of a good paradigm
- Explanation for Type II error (false negatives)
- Provides a ceiling on predictive model performance (**noise ceiling**)

# NOISE CEILING

- Maximum predictive performance of a model is limited by repeatability of the data

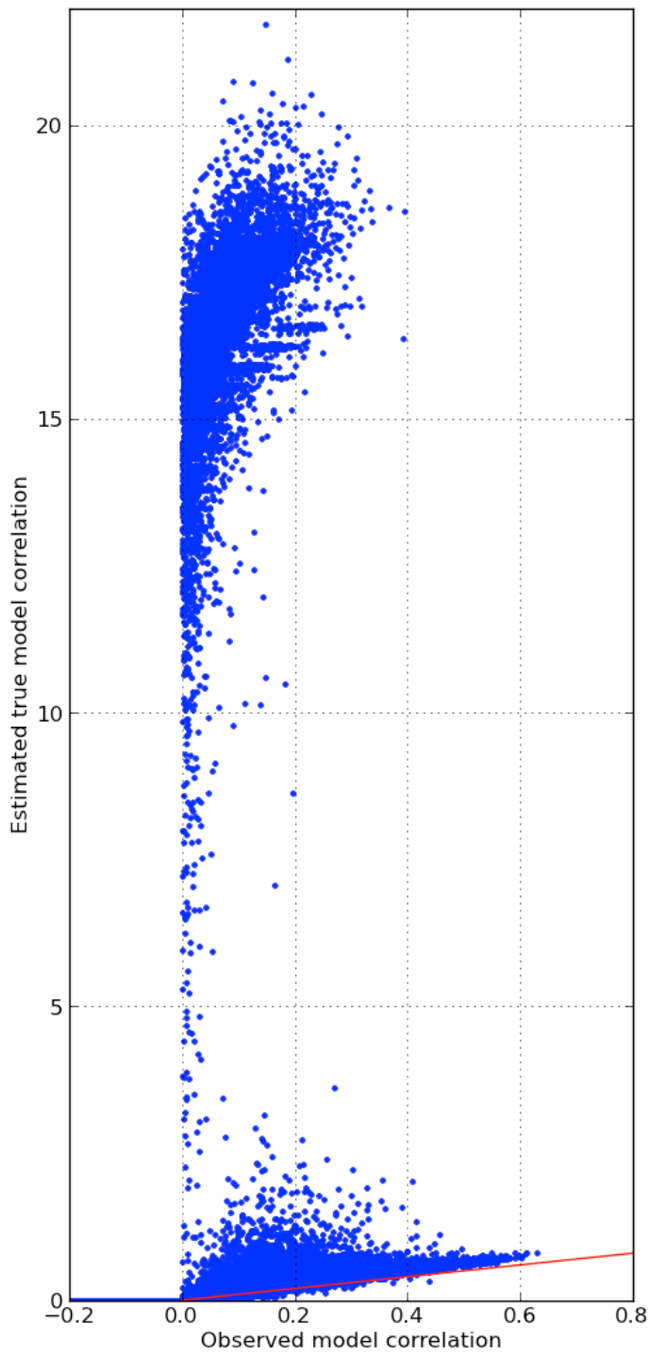
- Even with $n$ repeats, the average response is still noisy!

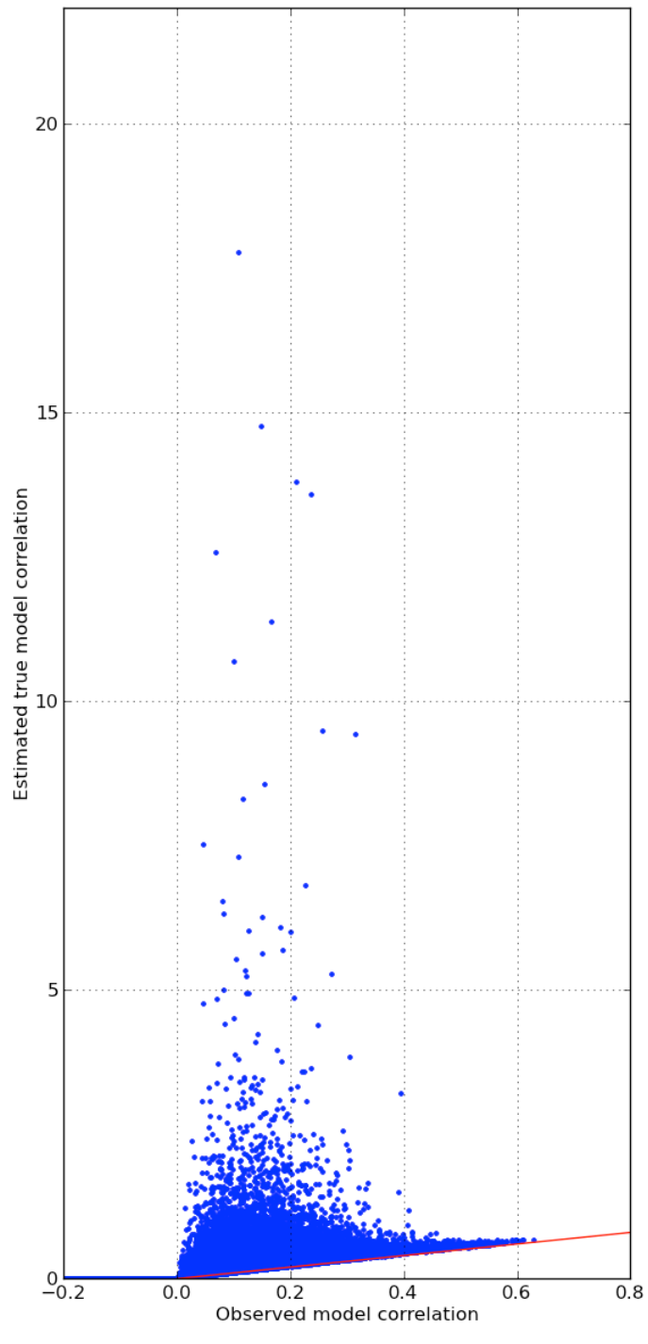
# NOISE CEILING

- Many approaches:
  - Sahani & Linden (2003)
  - Hsu, Borst, & Theunissen (2004)
  - David & Gallant (2005)
  - **Schoppe et al. (2016)**
- All have problems with very noisy data (e.g. fMRI)

# NOISE CEILING

David 2005 method  HBT 2004 method



# NOISE CEILING

- Recommended procedure given in:
  **Schoppe, Harper, Willmore, King, & Schnupp (2016)**

- (But there’s room to improve on this!)

# IS REPEATABILITY EVERYTHING?

- ***No!***

- *Thought (fMRI) experiment:* average together all the voxels in the brain.

Does the resulting megavoxel have high repeatability? ***Yes!***

Is it useful? ***No!***

# IS REPEATABILITY EVERYTHING?

- Repeatability is ***GOOD*** for comparing:
  - Across response channels (e.g. voxels) in same dataset
  - Across different types of stimuli
  - Across data acquisition methods where spatial and temporal resolution are preserved

# IS REPEATABILITY EVERYTHING?

- Repeatability is ***BAD*** for comparing:
  - Across data acquisition methods where spatial or temporal resolution are ***NOT*** preserved

# IS REPEATABILITY EVERYTHING?

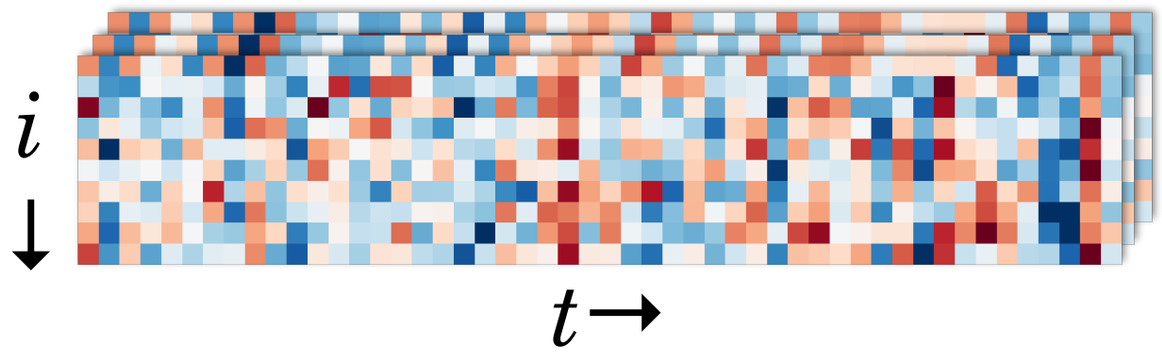
- Repeatability is susceptible to the *information trade-off problem*
- You can increase repeatability by sacrificing information
- Thus, repeatability can be “falsely” inflated

# *PREGUNTA*

**Can you think of a metric for data quality that could not be inflated by sacrificing information?**

- **Please:**
  - Think about this question for 2 minutes
  - Turn to your neighbor and discuss what you thought of

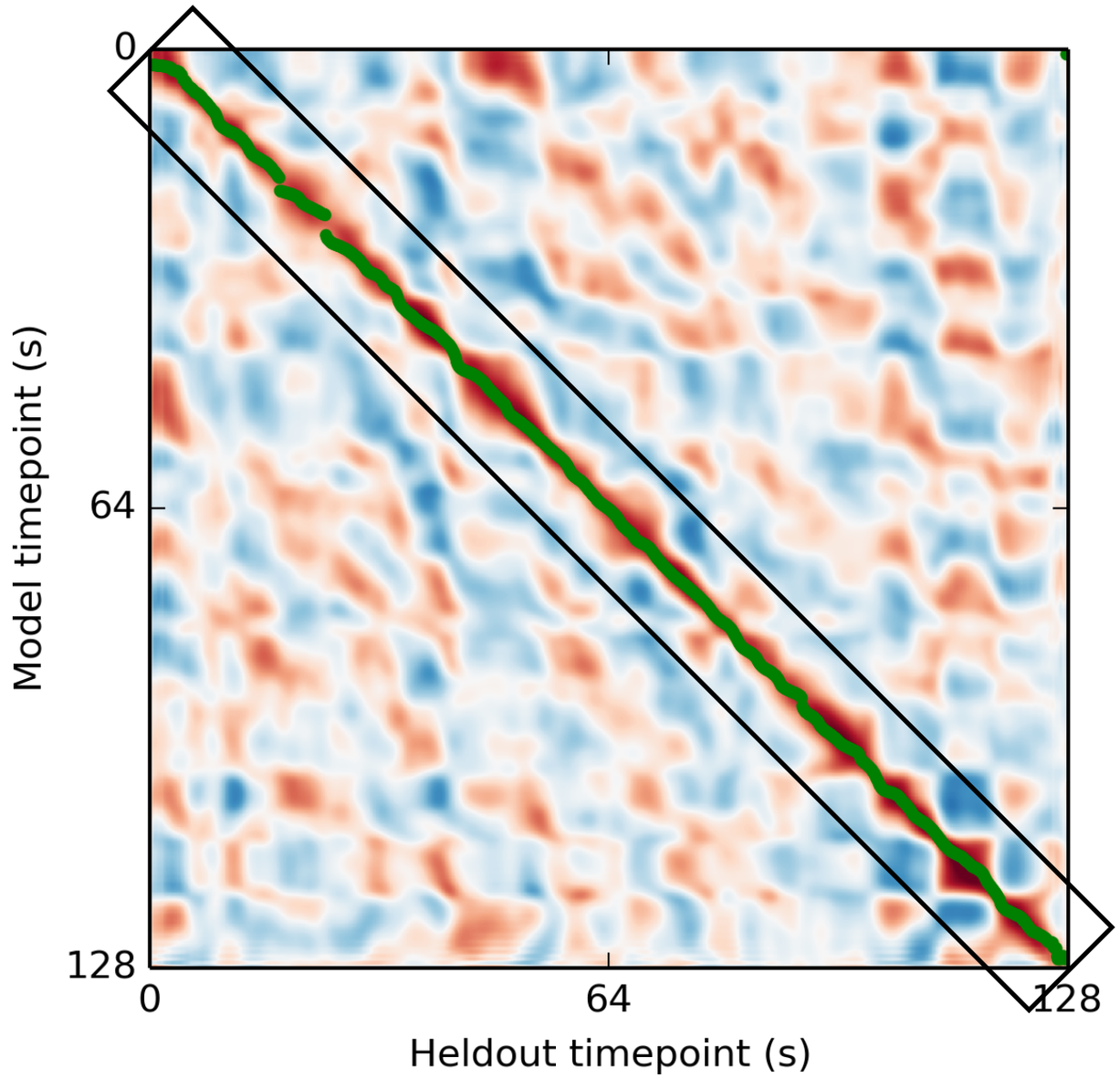
# TIMEPOINT CLASSIFICATION

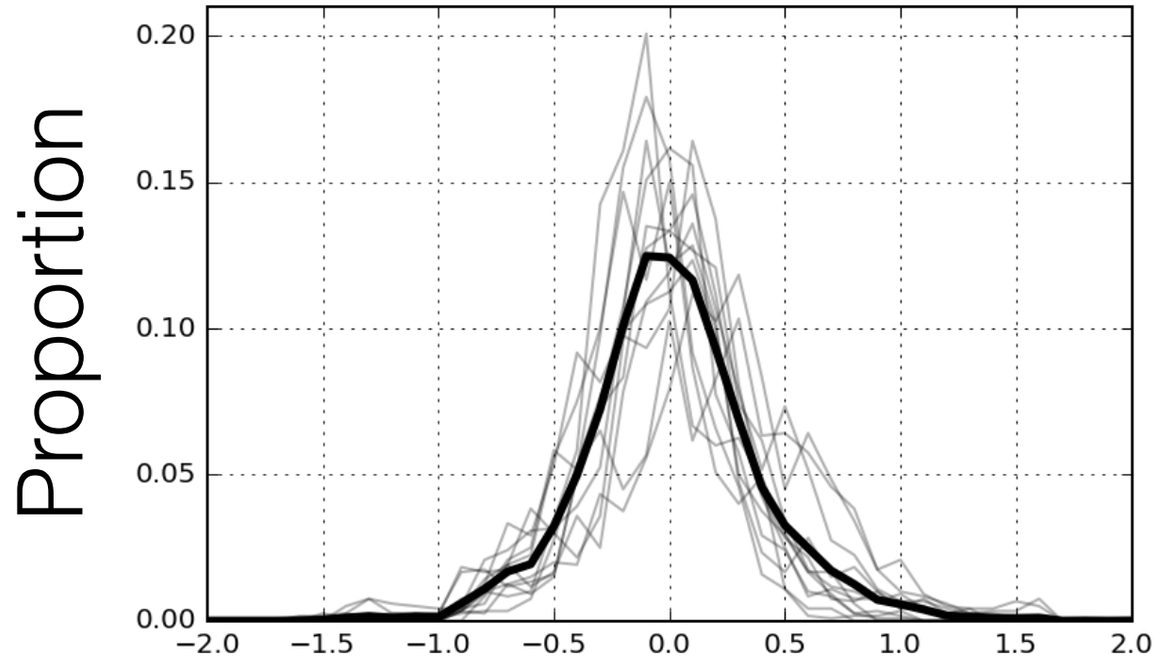



1. *(Optional: temporally up-sample data)*
2. Average $n-1$ repeats
3. In $n$'th repeat, take timepoint $t^*$
4. Decide which of $T$ timepoints in average response best matches $t^*$ (by correlation)

*h/t James Gao, Anwar Nuñez*

# TIMEPOINT CLASSIFICATION

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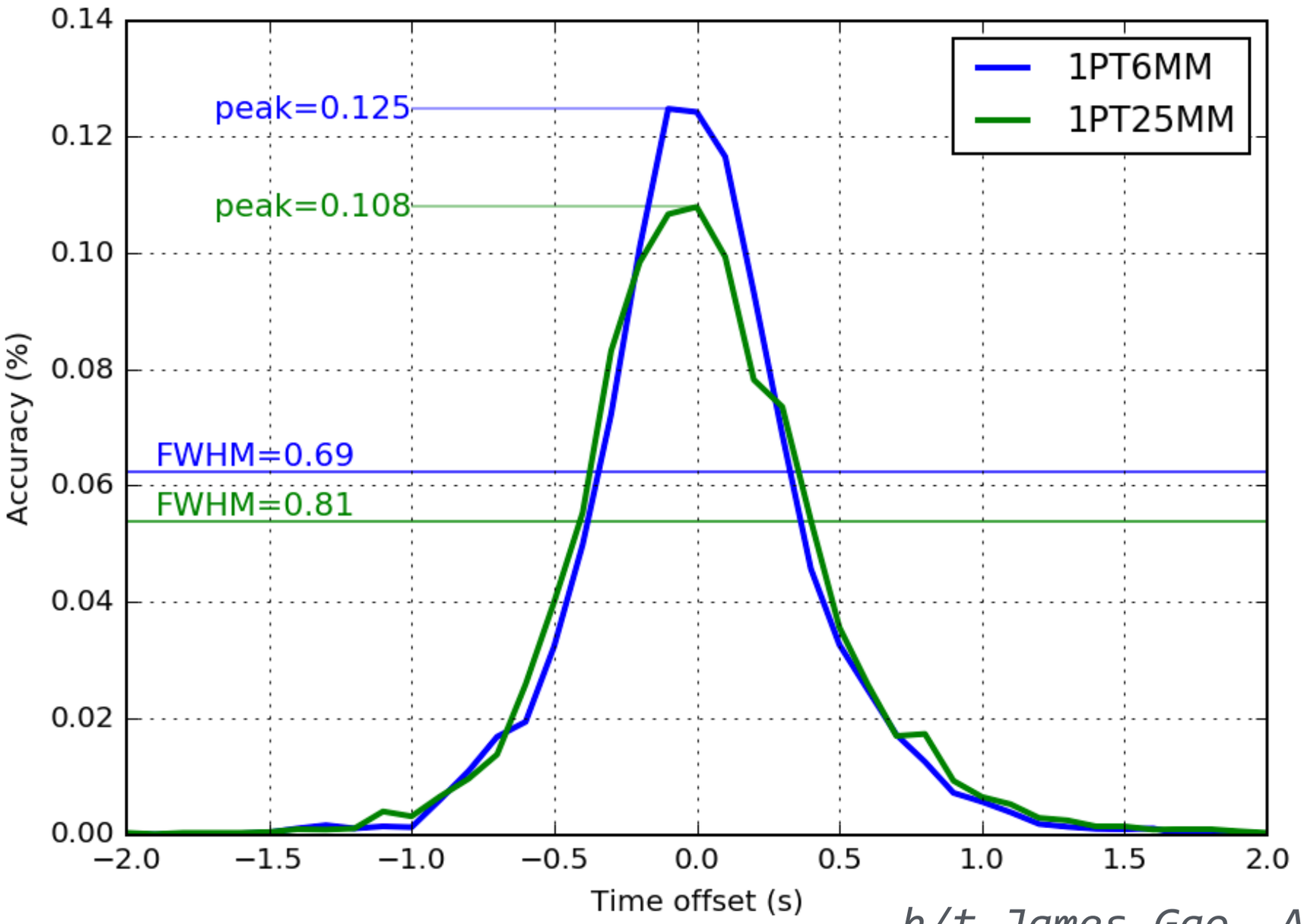
# TIMEPOINT CLASSIFICATION




*h/t James Gao, Anwar Nuñez*

# TIMEPOINT CLASSIFICATION

- A measure of how much information there is about the stimulus in the measured responses

- Perhaps a more absolute (& thus comparable) measure than repeatability

*h/t James Gao, Anwar Nuñez*

# TAKEAWAYS

- Data quality is important

- Learn how to measure data quality

- Before doing an experiment, cycle:
  (1) select data collection parameters,
  (2) collect test data,
  (3) assess data quality

# THANKS