Challenges for Analyzing Slow Rhythms in MEG Data

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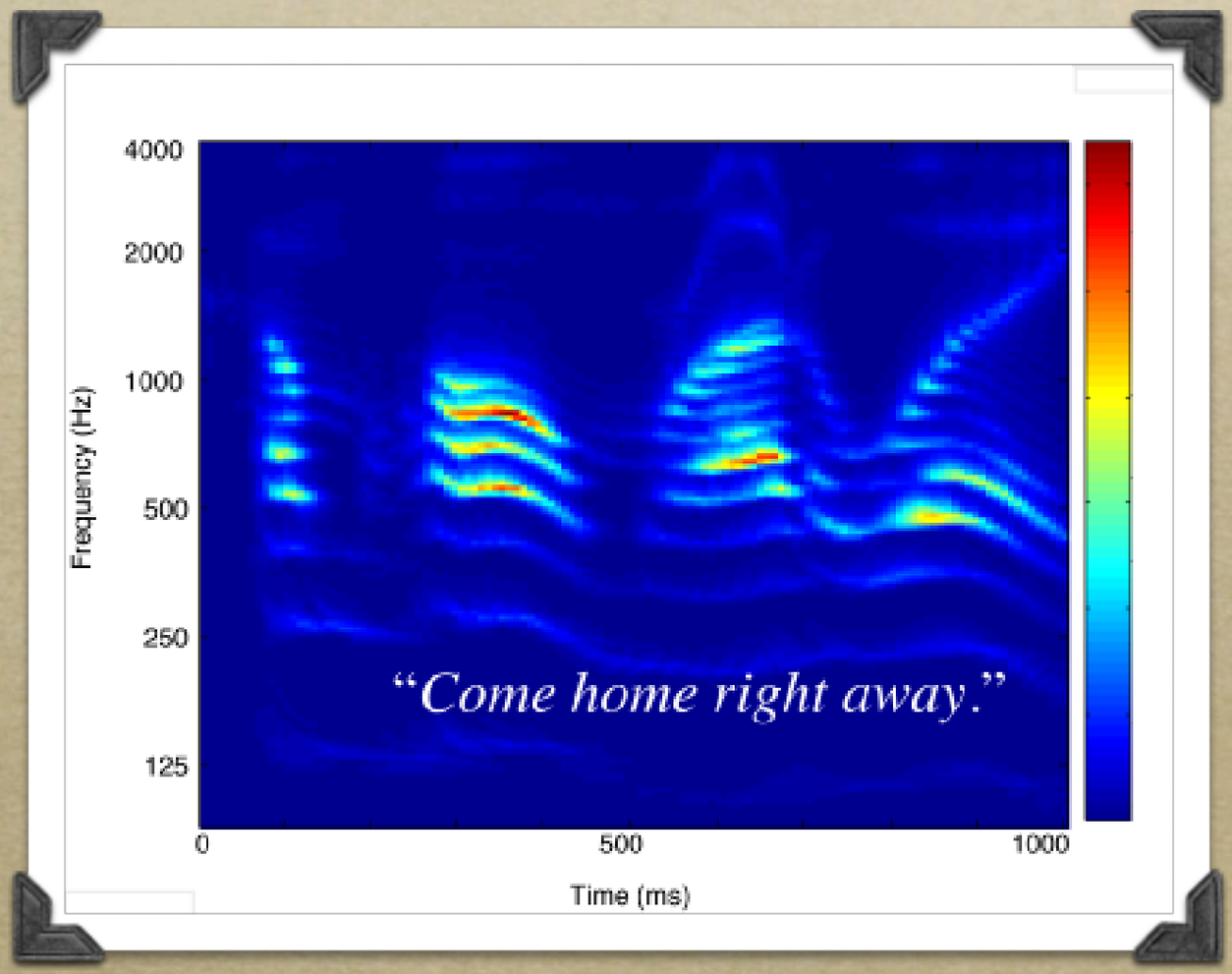
Supported by NIH
R01 AG 027573
R01 DC 007657
R01 DC 008342
R01 DC 005660

Auditory Rhythms in Speech

- *Amplitude Modulation (AM)*
- *Frequency Modulation (FM)*
- *Other (e.g. binaural)*



Slow Neural Rhythms

- 2 – 20 Hz *Critical rates for speech*

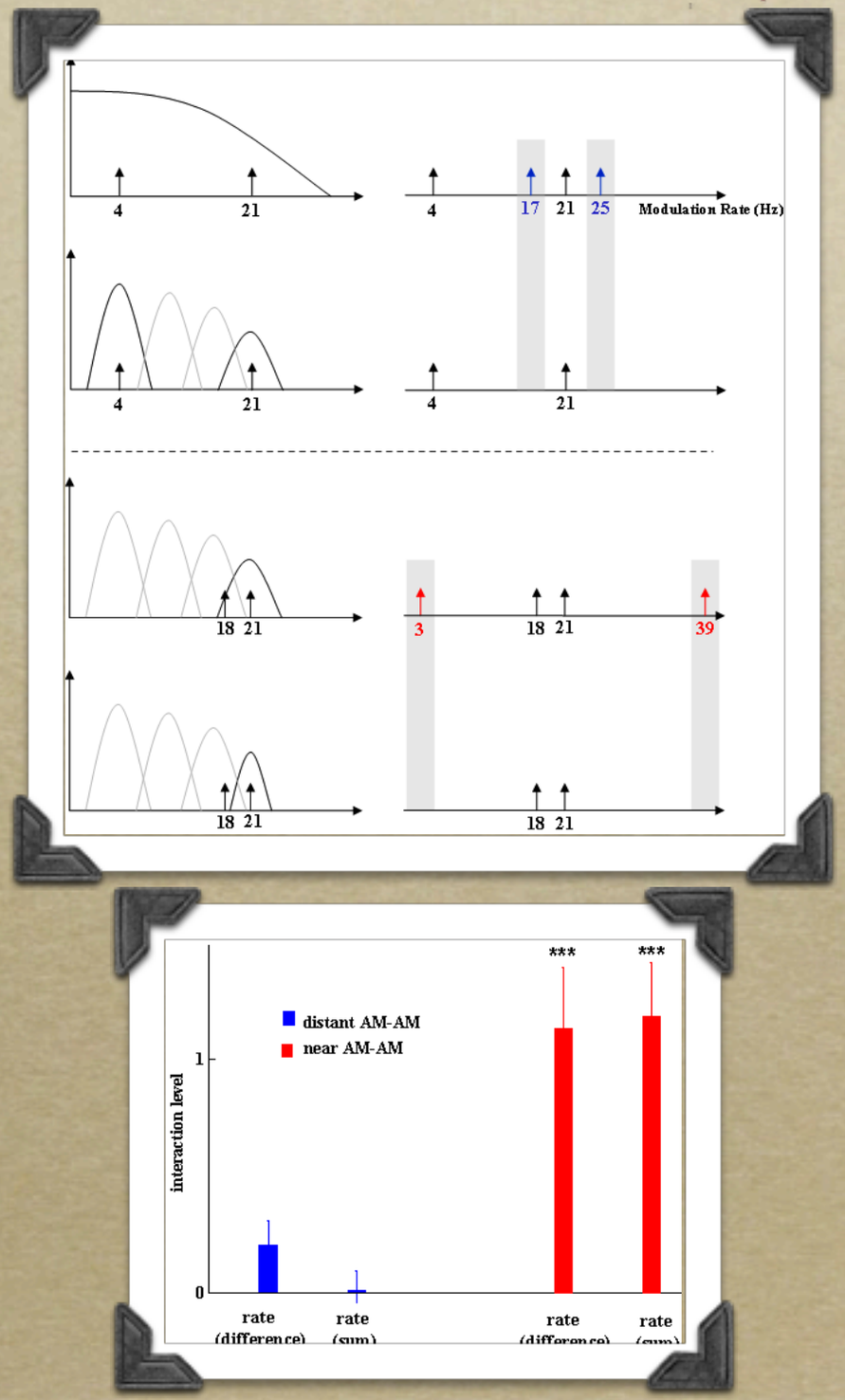
generating, or competing with

- 2 – 7 Hz *Delta, Theta*
- 8 – 12 Hz *Alpha*
- 12 – 30 Hz *Beta*
- 30+ Hz *Gamma*

Slow Rates ⇒ Speech Processing

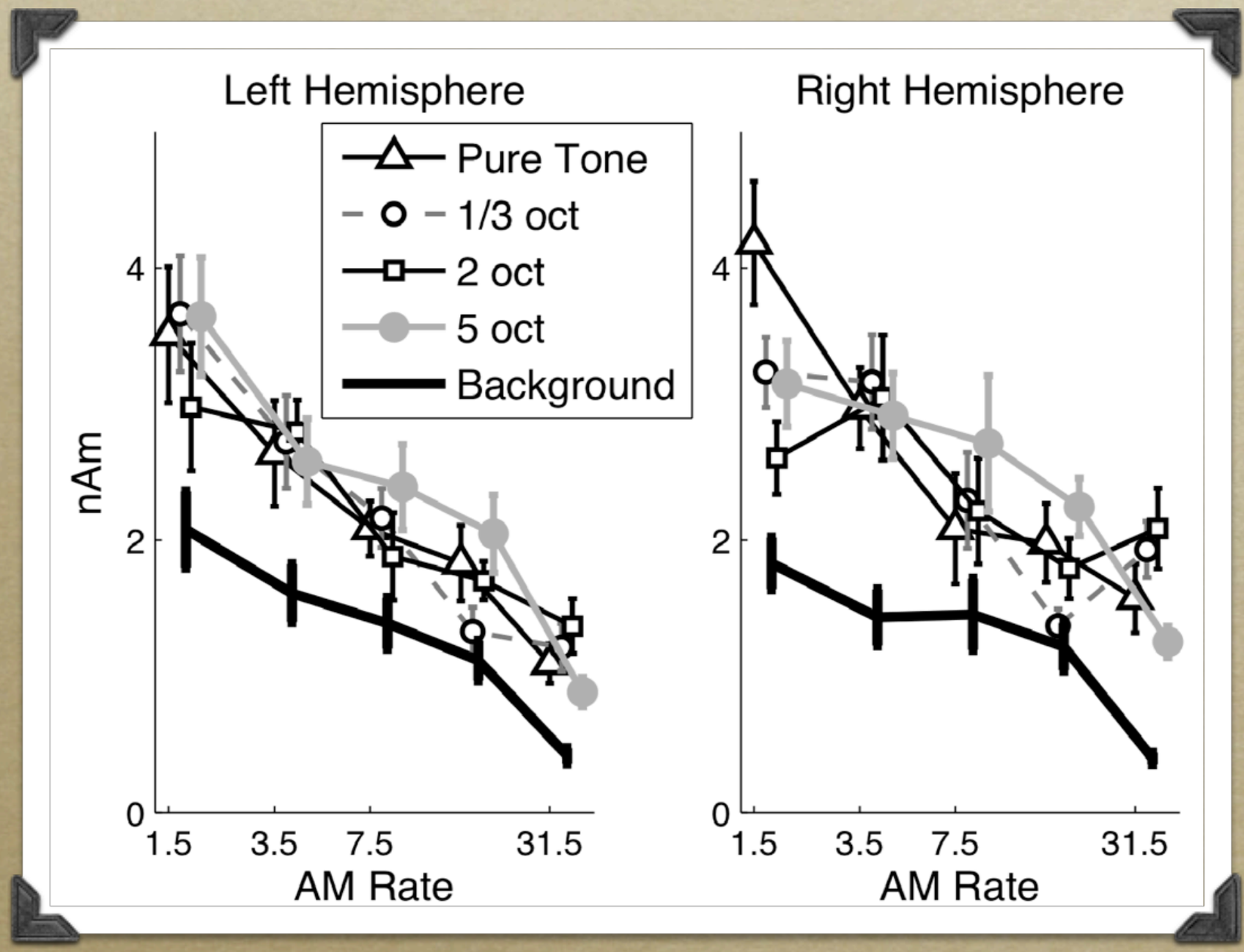
- *Cortical Modulation Filterbanks*

- *Cortical encoding of multiple modulations analogous to cochlear encoding of multiple frequencies?*



Juanjuan Xiang (*in preparation*)

Slow Rate = Noisy Background



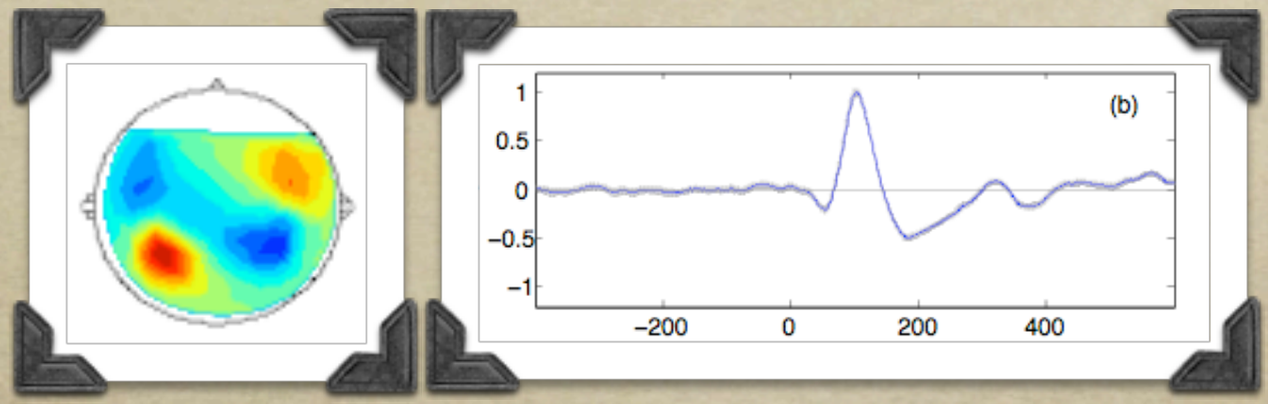
Yadong Wang, Nai Ding (*in preparation)*

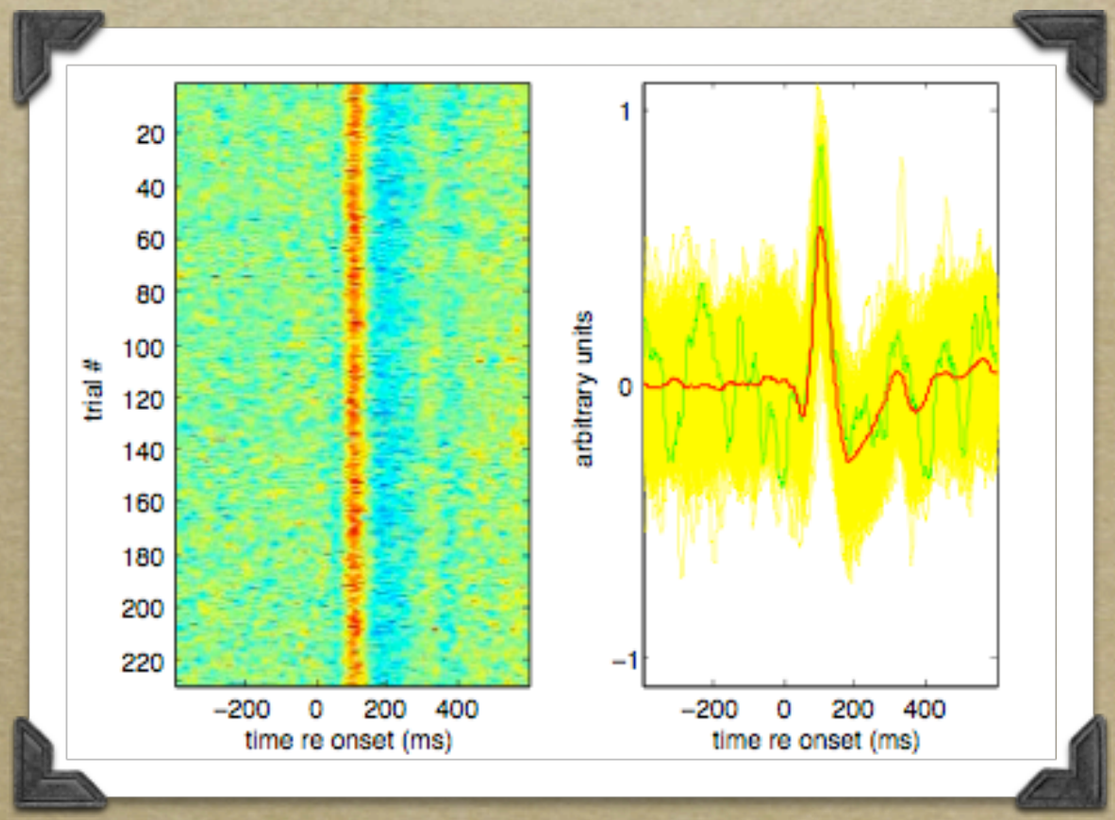
Denoising is Critical

- *Focus: Neural background noise*
- *Example: Data driven spatial filtering, e.g. Denoising Source Separation (DSS)*
- *Generates spatial filters & their outputs ("components")*
  - *ordered by reproducibility*
  - *1st component "maximally reproducible" = stimulus driven*

Temporal DSS Examples

- *Most reproducible filter & component*
- *Optimally filters **out** trial-to-trial-variable signal = neural noise*
- *Filter can be applied to other signals, e.g. single trials*

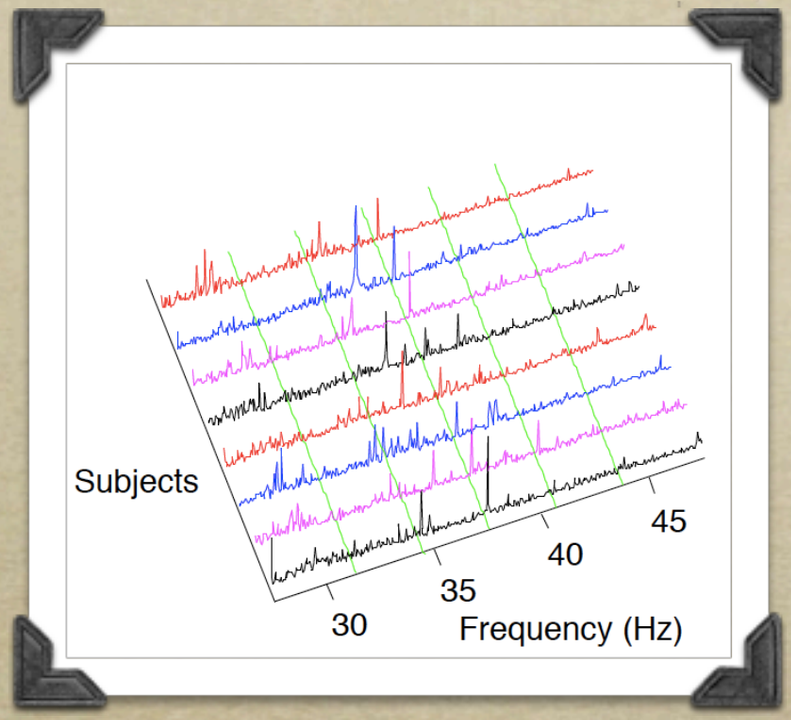




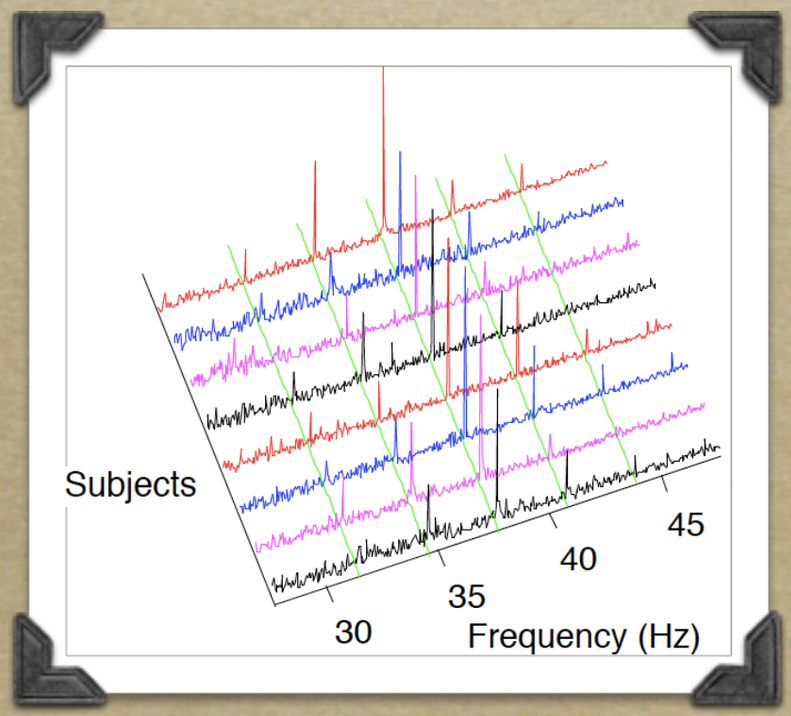
de Cheveigné & Simon, J. Neurosci. Methods 2008

Spectral DSS Examples

Frequency Spectrum before DSS



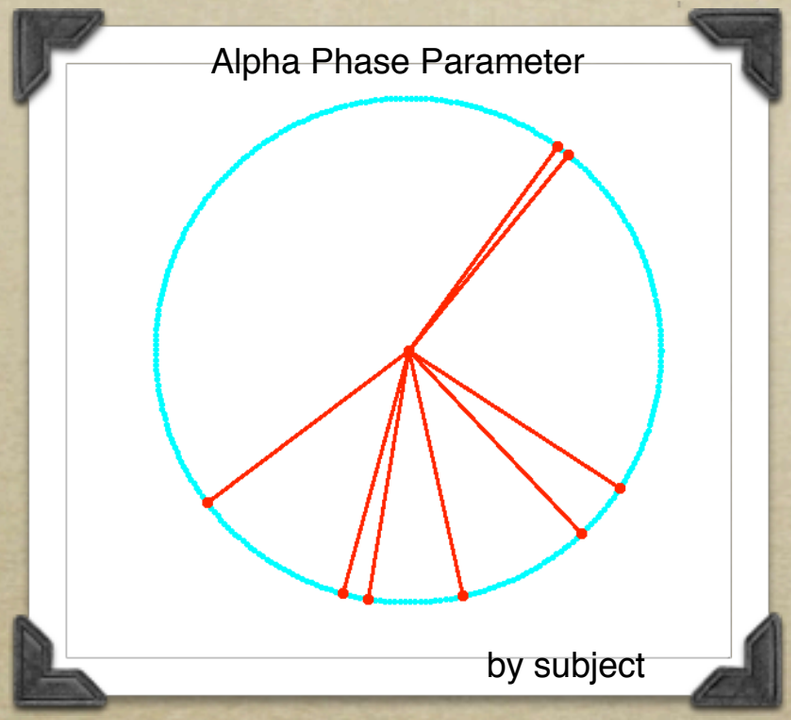
Frequency Spectrum after DSS



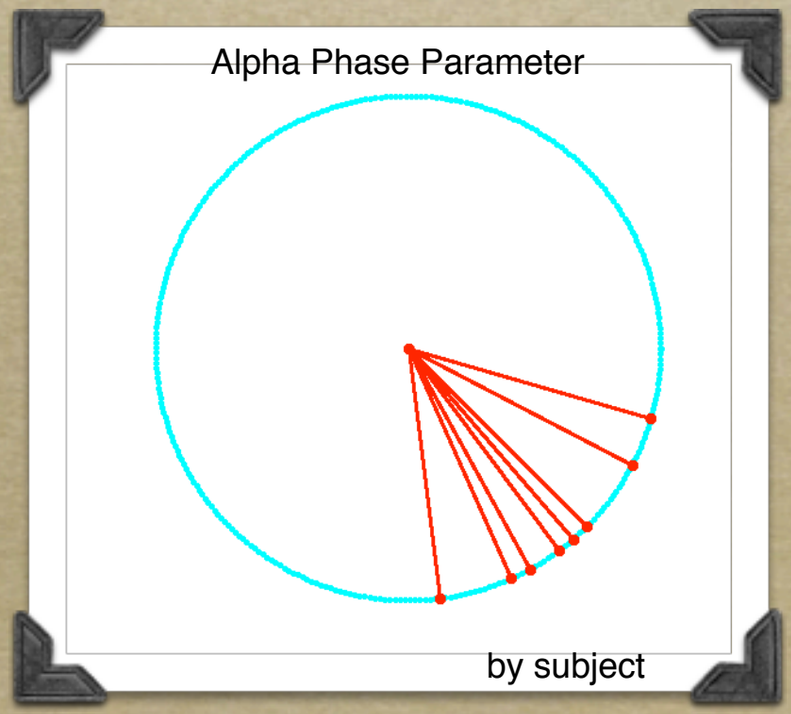
Ding & Simon, J. Neurophysiol 2009

Phase DSS Examples

Phase Spread before DSS



Phase Spread after DSS



Ding & Simon, J. Neurophysiol 2009

Challenges Overcome

- *With careful attention paid to noise and variability*

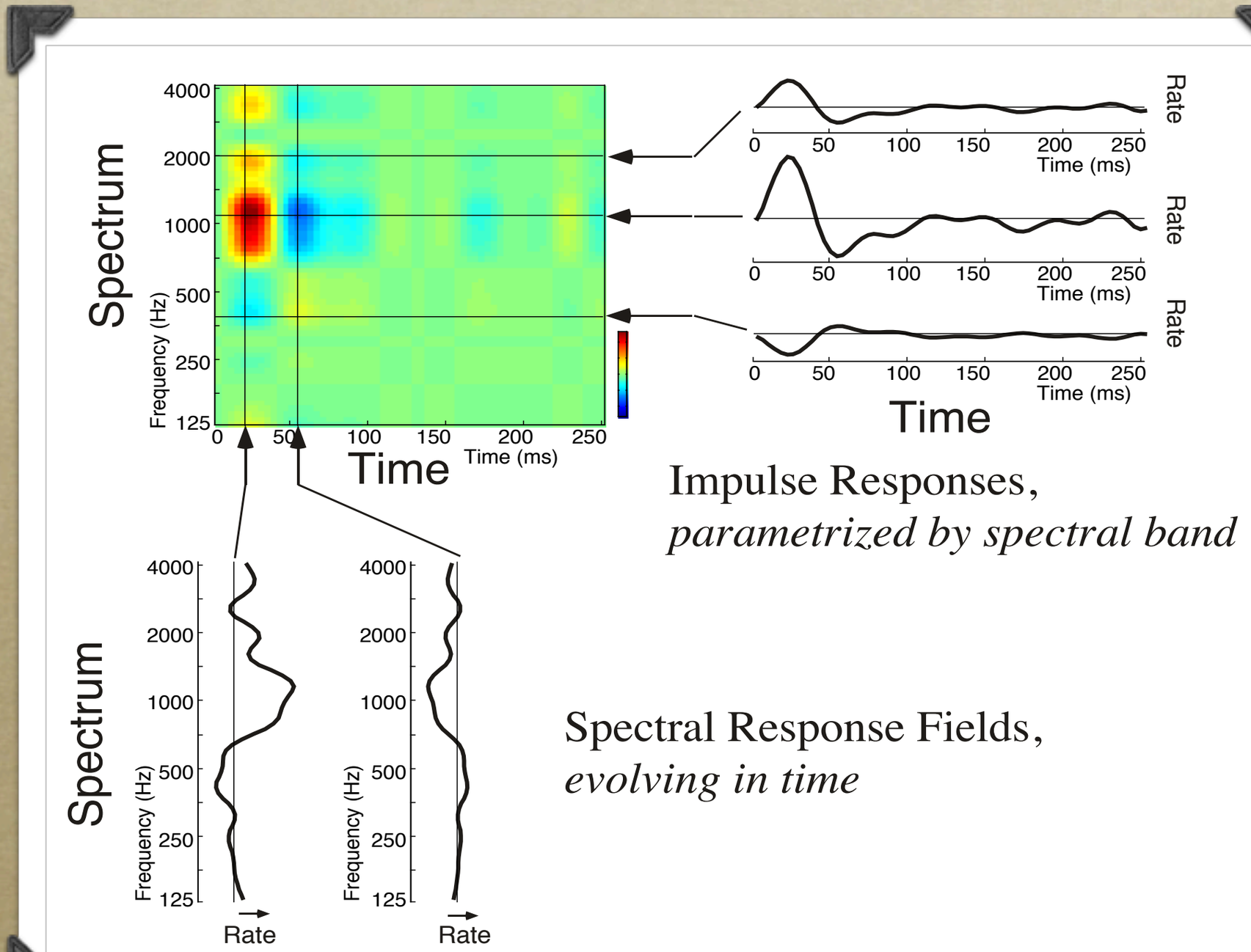
  $\Rightarrow$ *denoising, cross-validation, etc.*

  Faint, variable signals can be made robust & reliable

Application: Natural Speech

- Lengthy natural speech stimuli (2 minutes of “The Legend of Sleepy Hollow”).
- MEG response cleaned with DSS and reverse correlated with stimulus
- Robust MEG representation of Speech, even after a single presentation: STRF

Neuronal STRFs



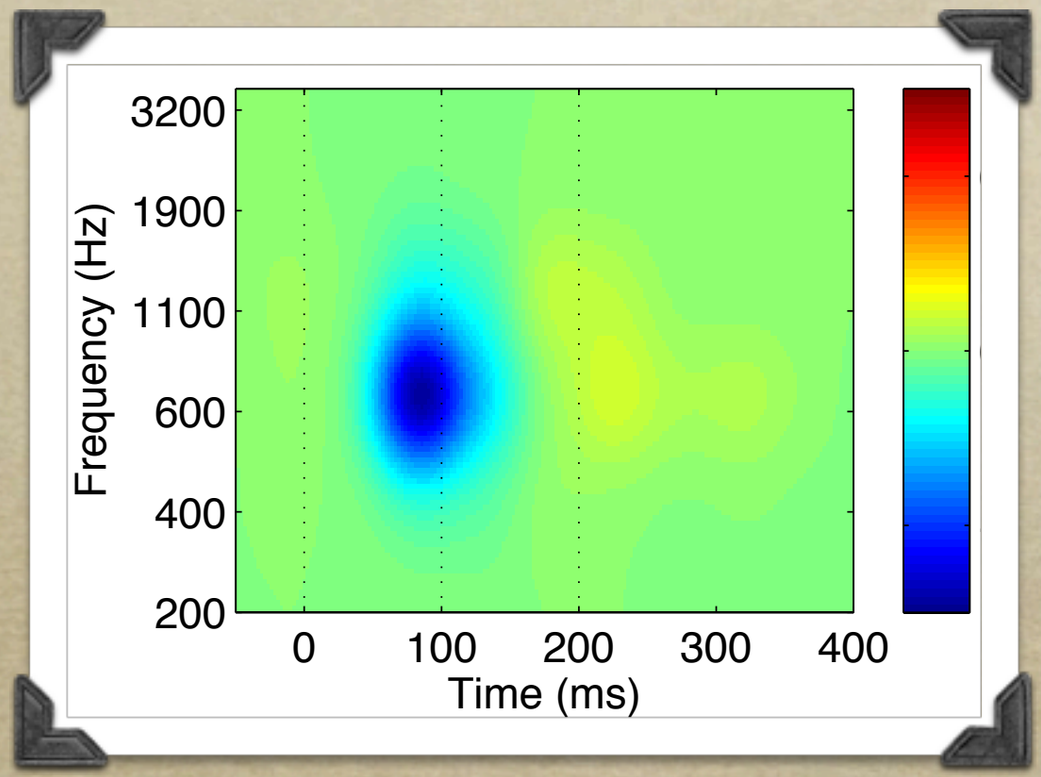
Simon et al. Neural Computation (2007)

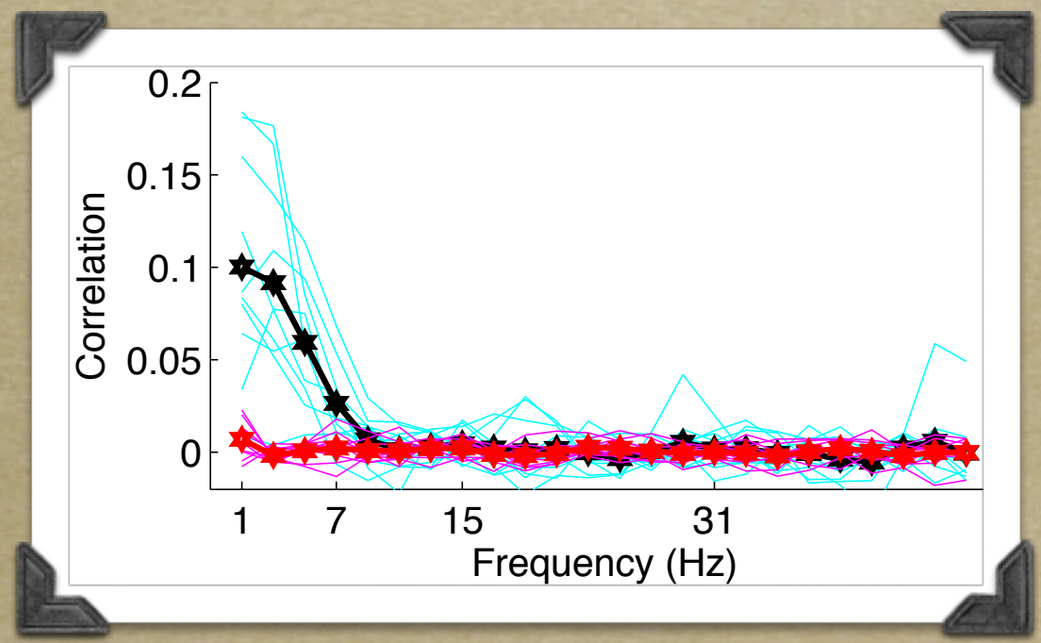
MEG Representation of Speech

- *Robustly represented by Spectro-Temporal Response Function (STRF)*

- *Stimulus representation dominated by frequencies from 500 to 1200 Hz*

- *Response dominated by slow frequencies < 8 Hz*

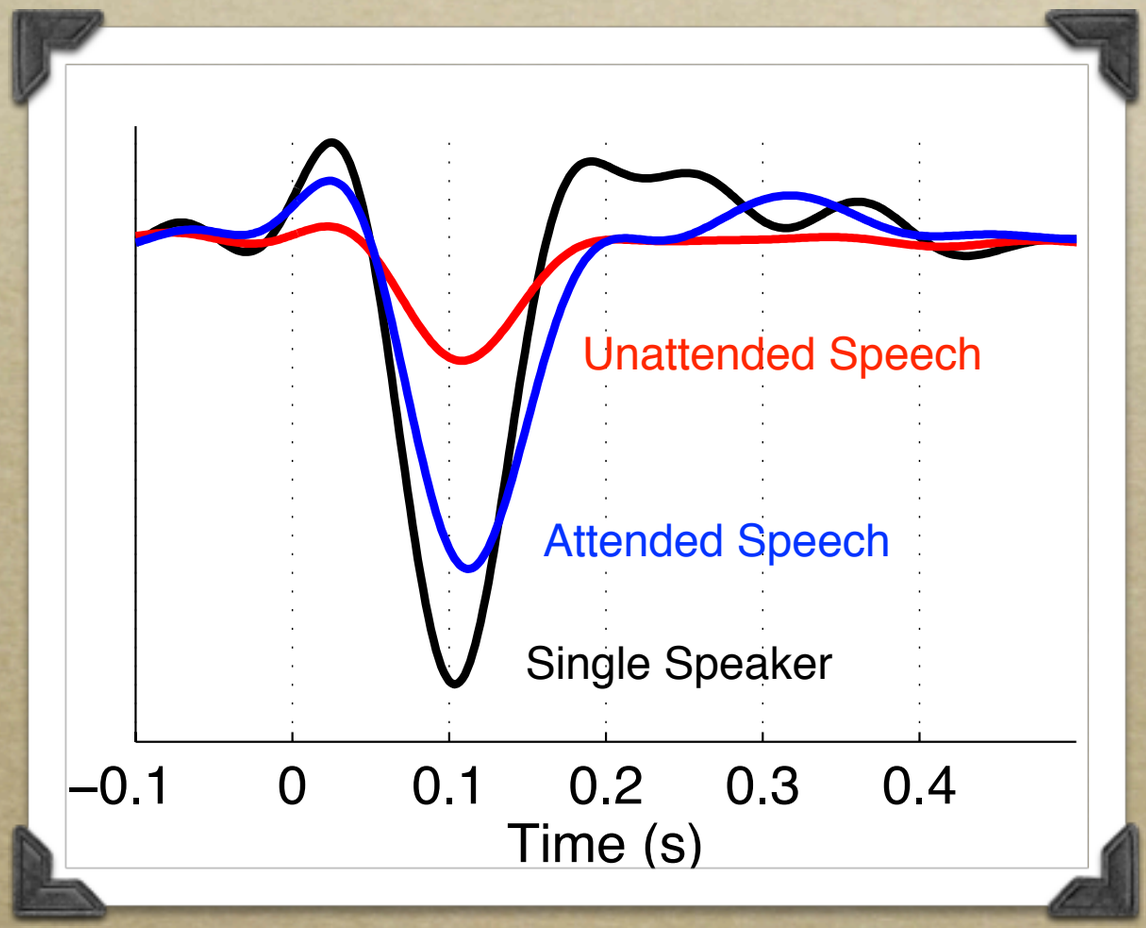




Nai Ding (*in preparation*)

Multiple Speakers No Problem

- *Speech impulse responses to speech from multiple simultaneous speakers*
- *Speech representation strongly modulated by attention*



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Summary

- *Slow rhythms critical to neural representations of speech*
- *Stimulus generated slow rhythms are easily masked by intrinsic rhythms and other neural background*
- *Neural representation of speech and other speechlike sounds can be made **visible** and **robust***

Significance by Frequency