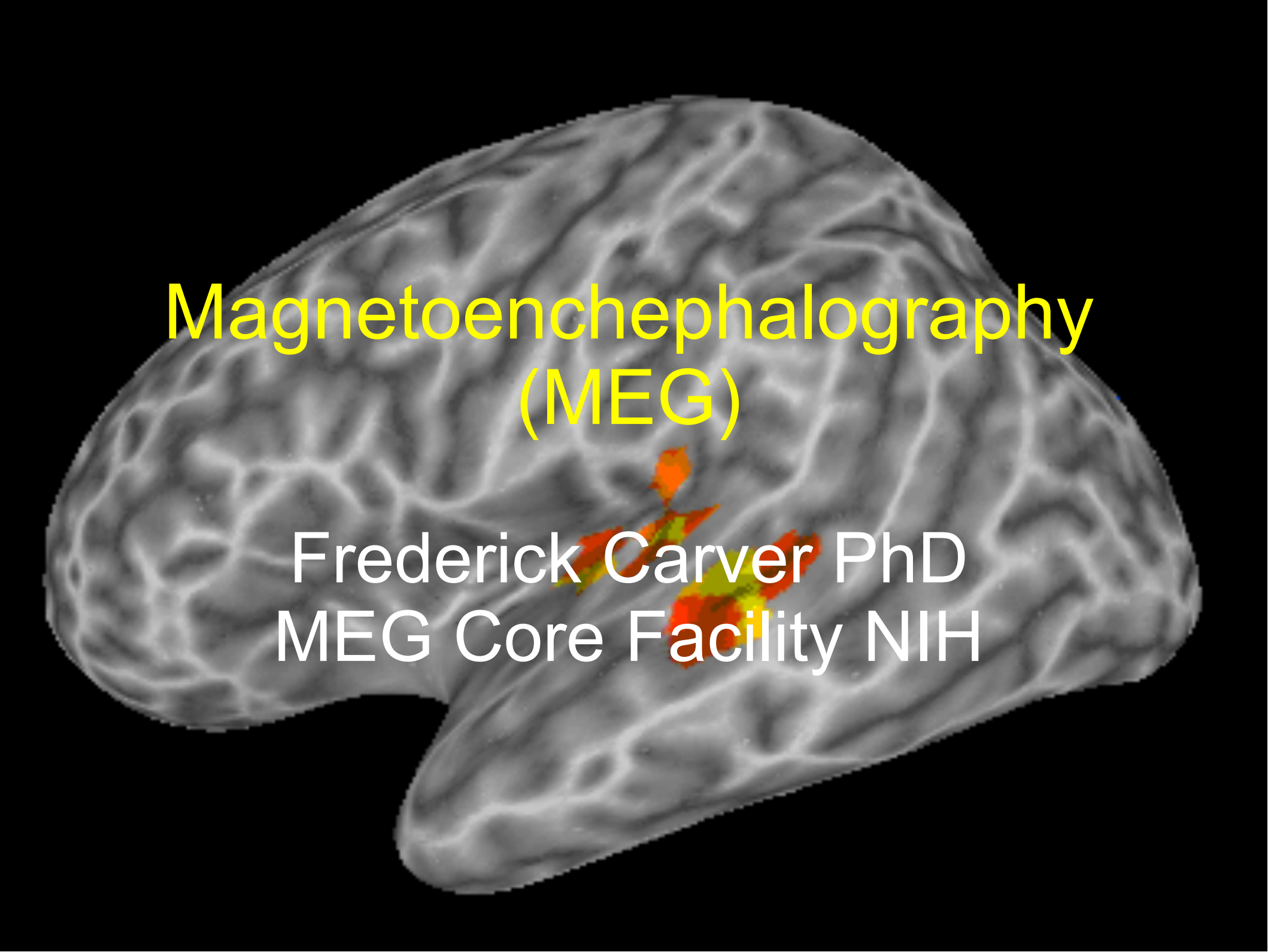
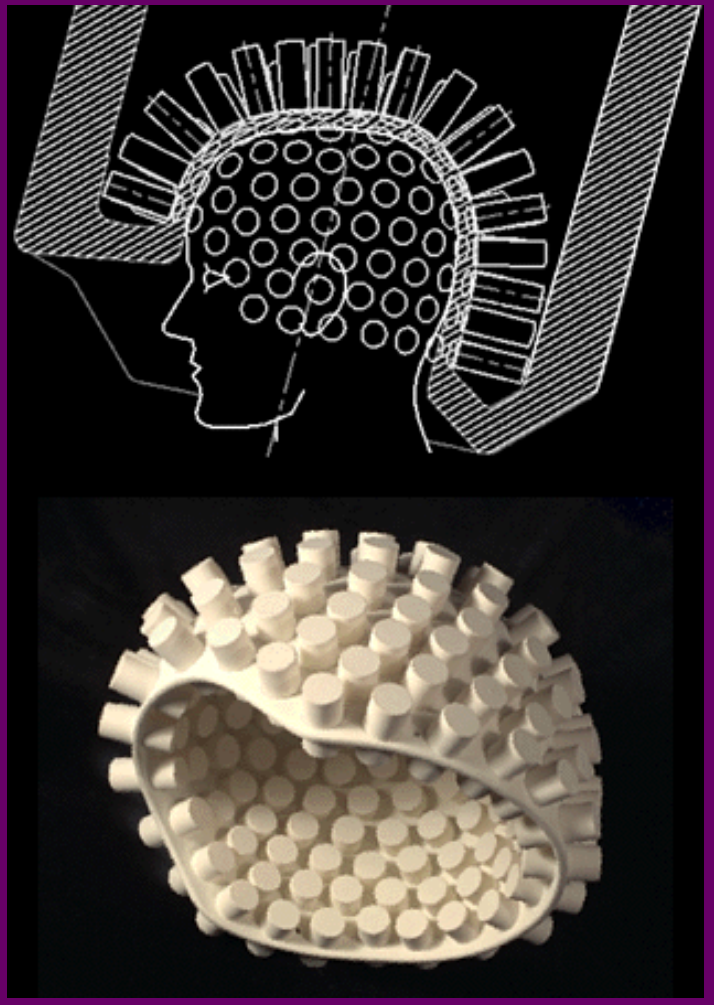
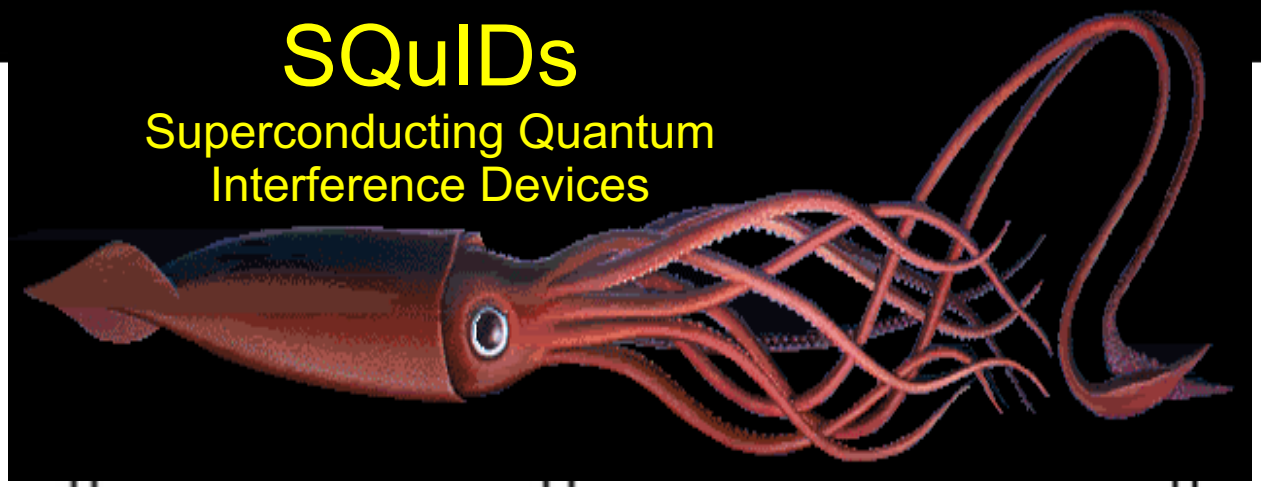

Magnetoenchephalography
(MEG)
Frederick Carver PhD
MEG Core Facility NIH

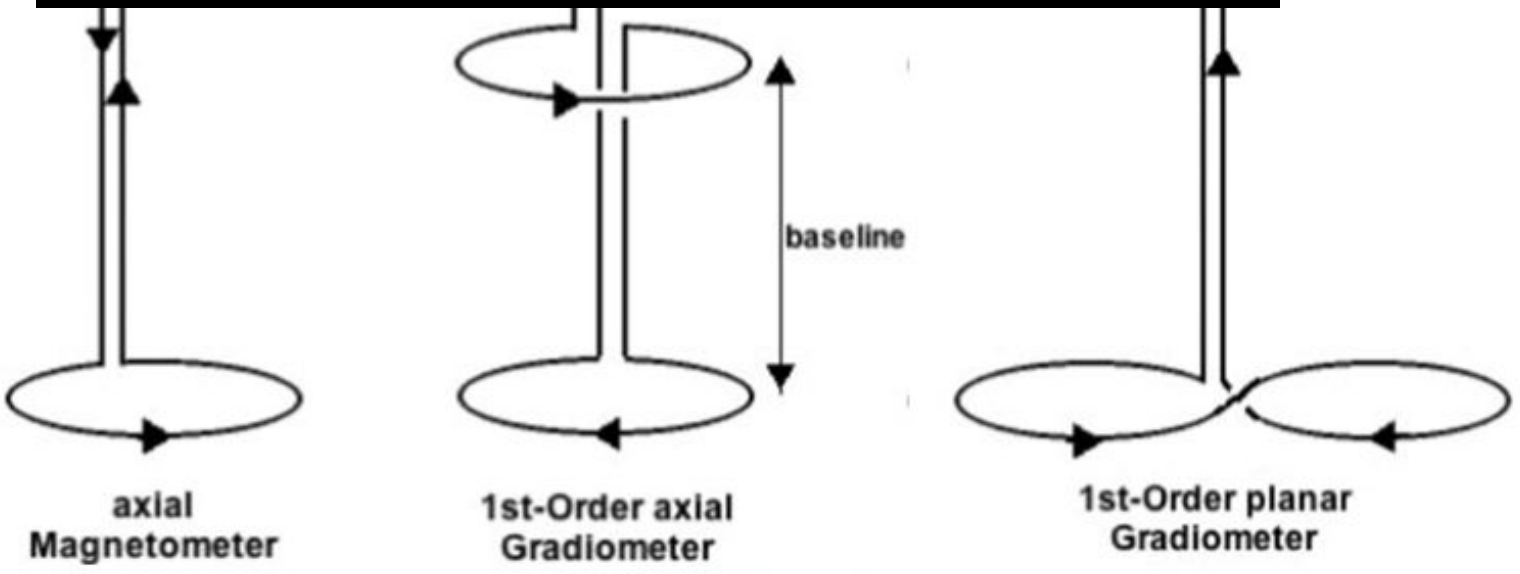
Our CTF system has 275 radial gradiometers, and 30 reference sensors (also EEG).



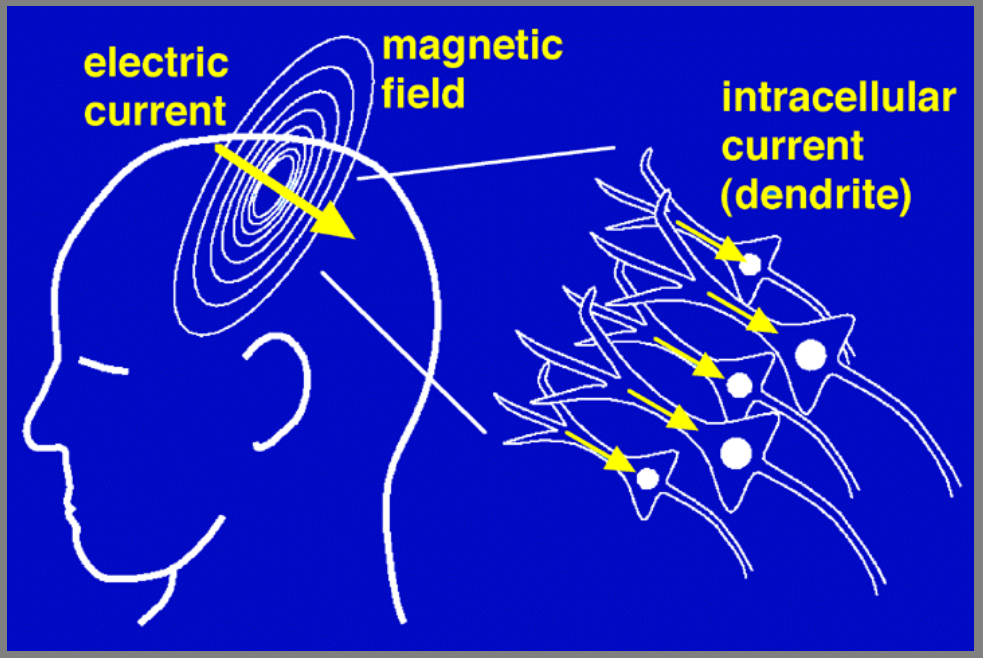
SQuIDs

Superconducting Quantum Interference Devices





Signal Source



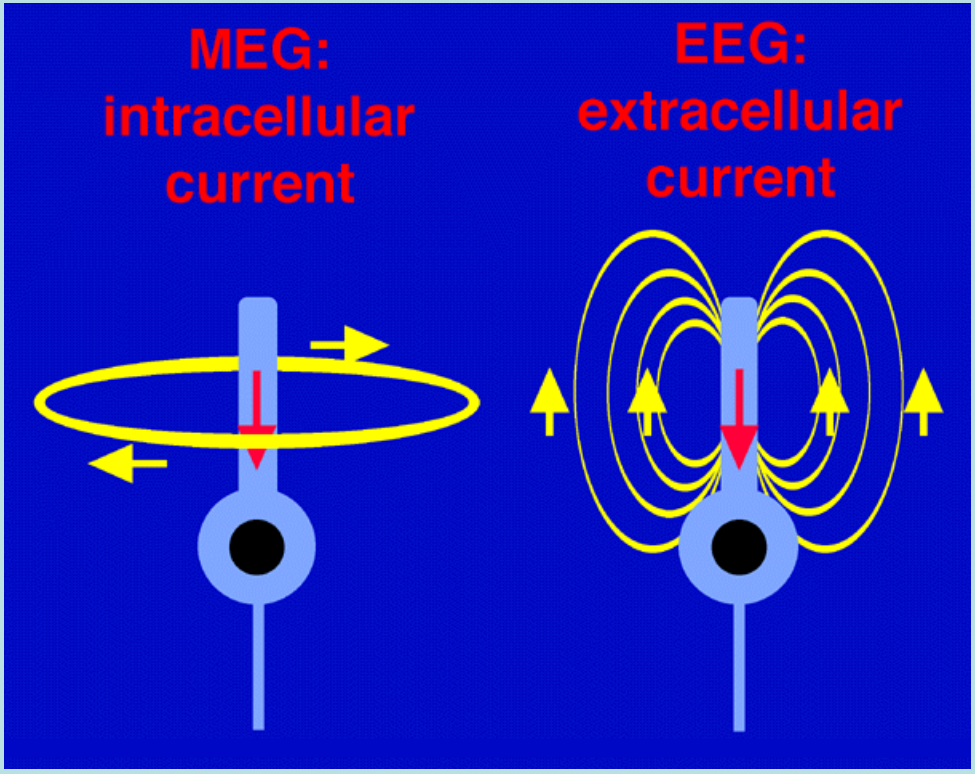
The long apical dendrites of cortical pyramidal cells are the theoretical source of MEG signals

Up to 10,000 parallel cells need to be active to produce measurable fields outside the head

A typical evoked field is on the order of 100 femto Tesla

($1fT = 10^{-15}T$)

Comparison to EEG

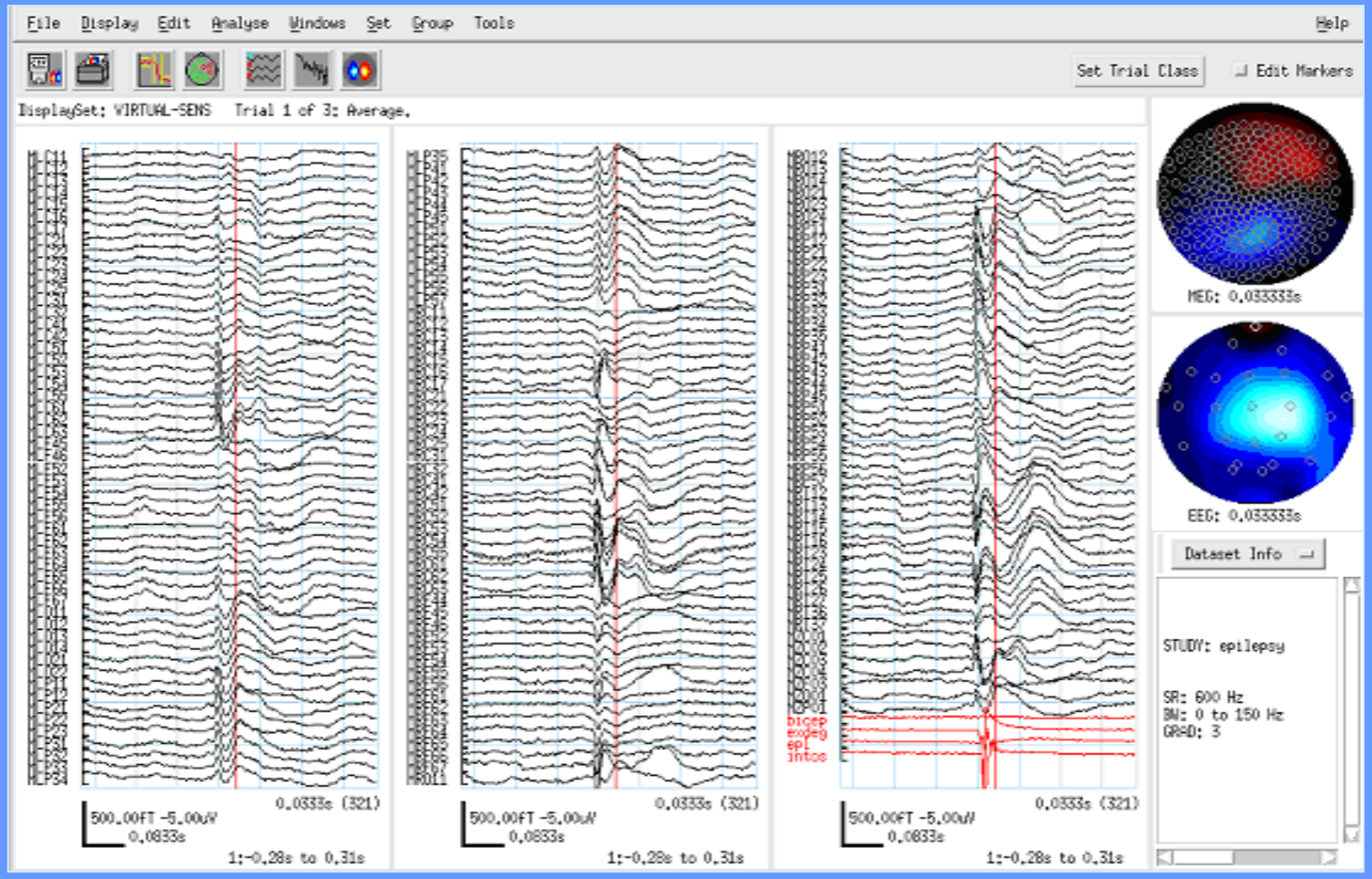


Magnetic fields pass through the skull without interference

Volume conduction distorts EEG signals making source reconstruction difficult

Some sources may be harder to see with MEG because of orientation, or cancellation. e.g. SMA

MEG Example



Epileptic spike associated with muscle twitch

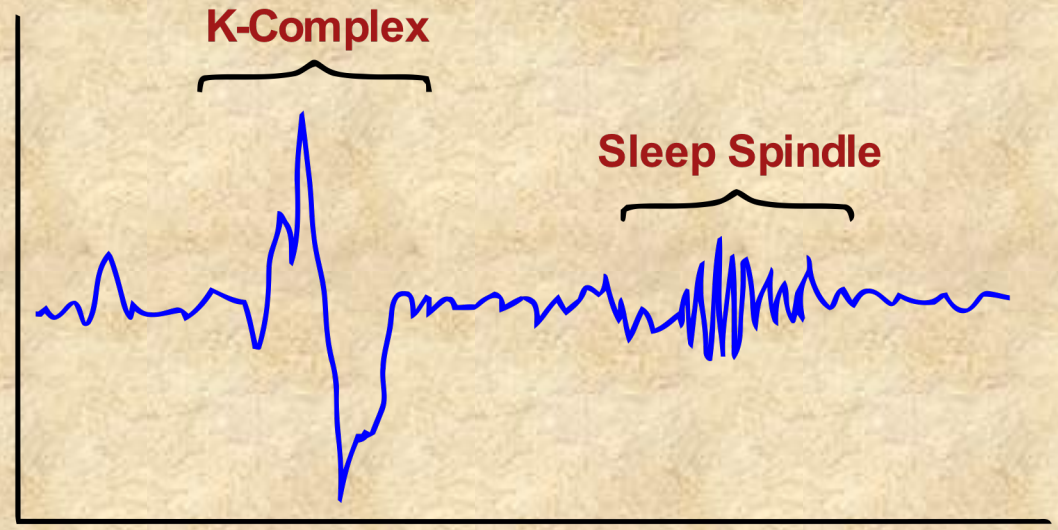
Sato et al.,
NINDS

Time Series Analysis

What are we looking for?

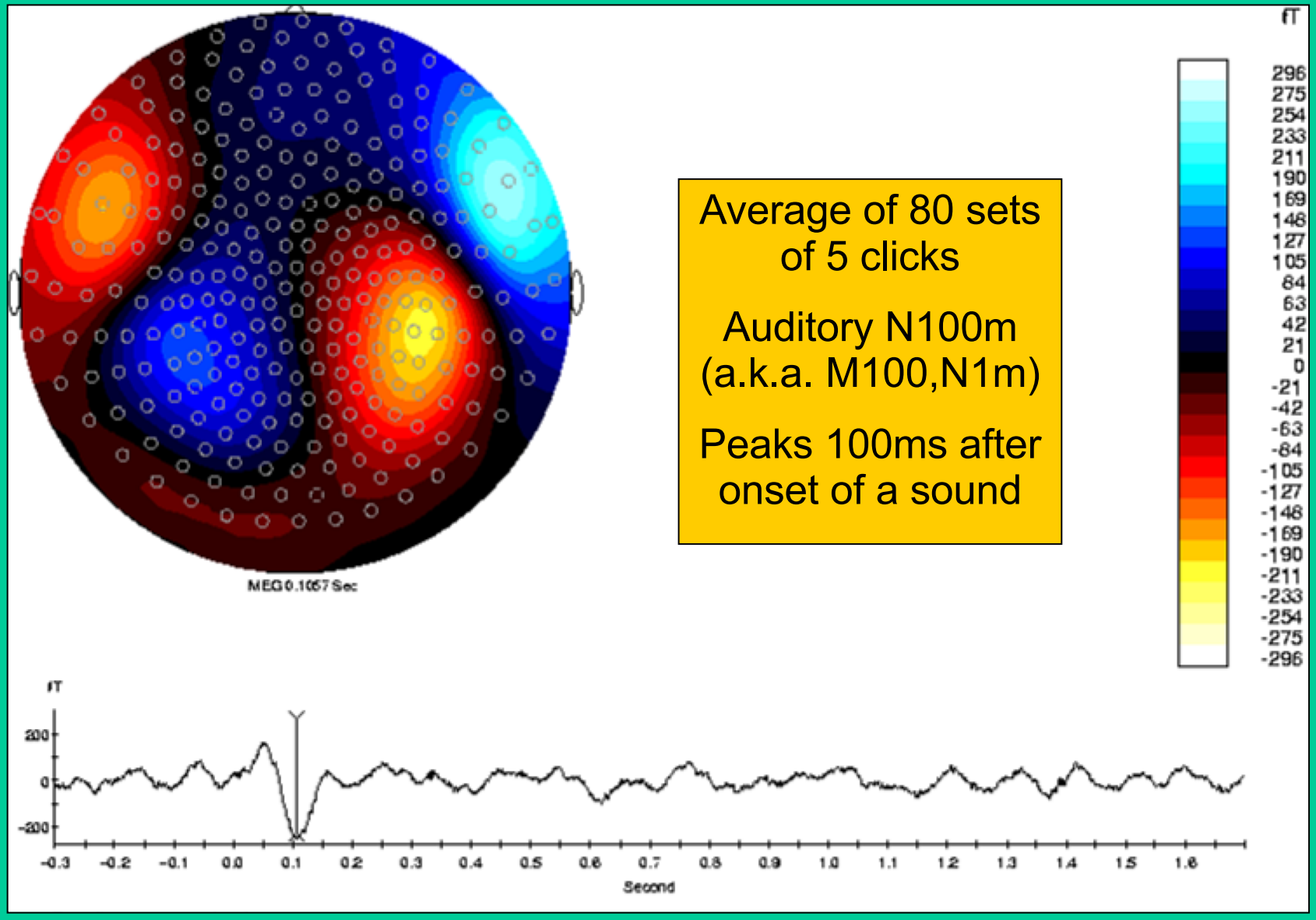
- Individual spikes or complex waveforms
  e.g. epileptic spike, sensory evoked response

- Oscillations at particular frequency bands
  e.g. theta (4-8Hz), alpha (8-13Hz), beta (14-30Hz), gamma (30-50Hz)



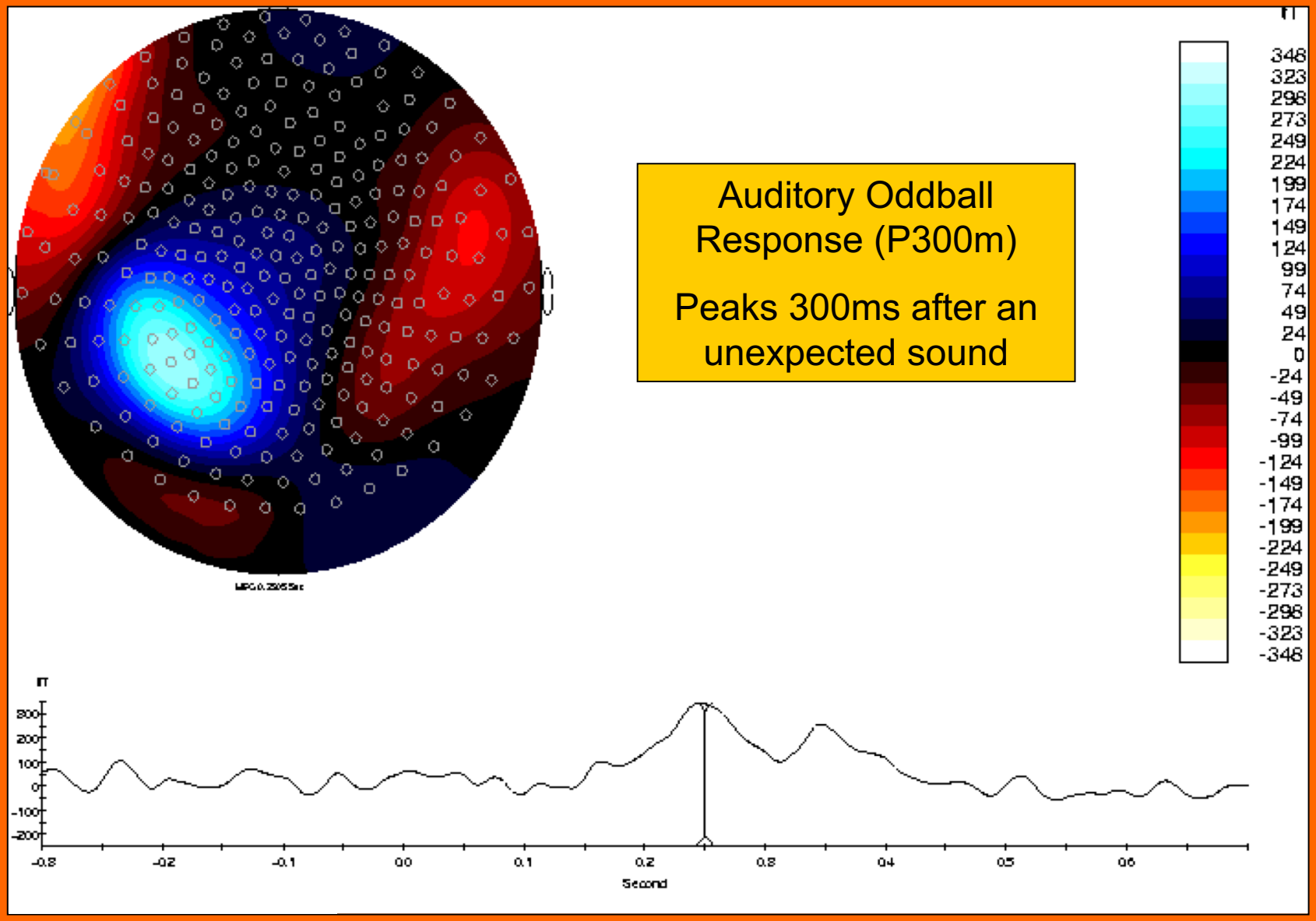
-wikipedia

- Evoked Fields
  - Time series averaged around an event
  - Often early sensory or motor responses

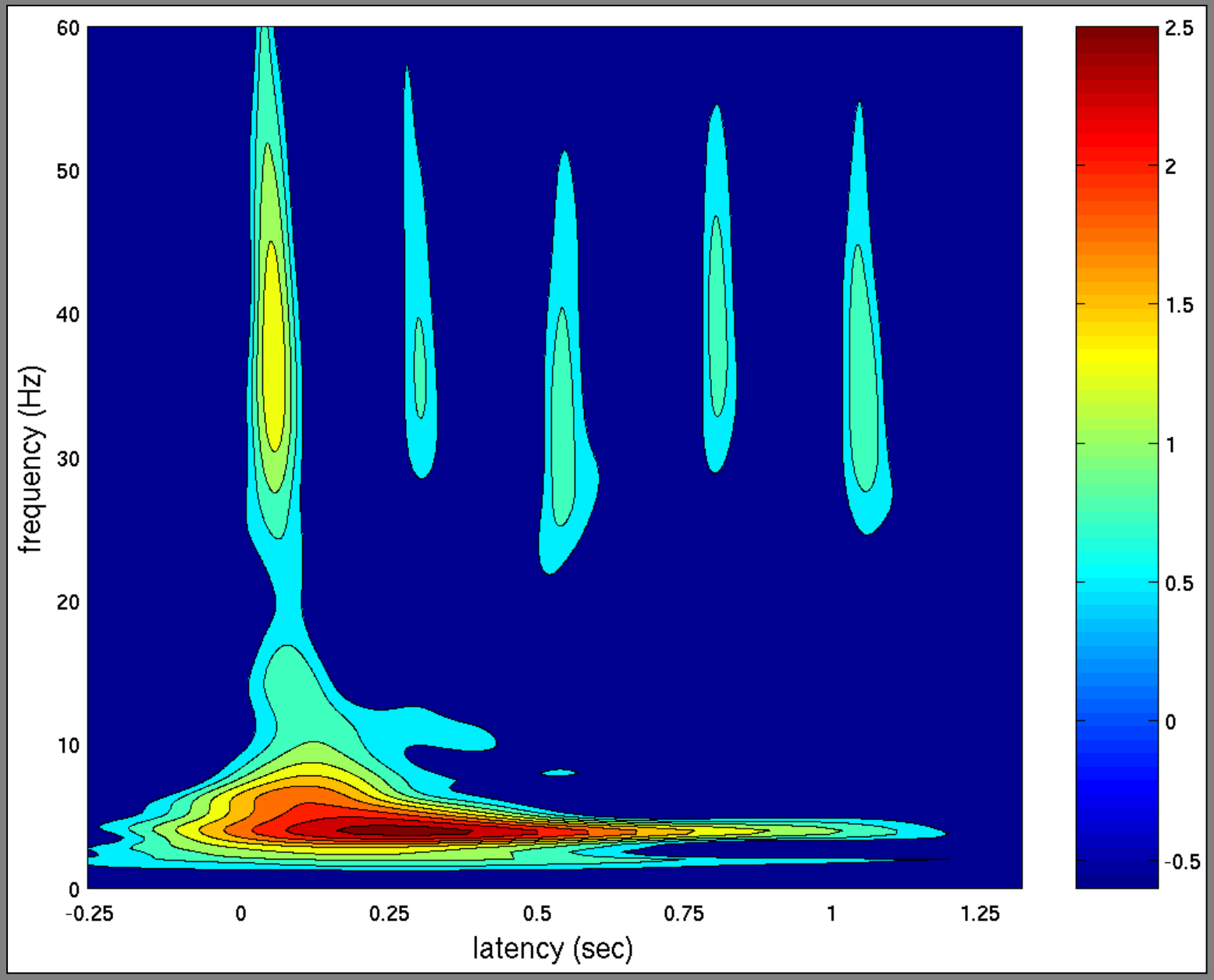


Event-related Fields (ERFs)

- More complex / later / depend on experimental context
- Can be ‘induced’ meaning not phase locked to stimulus

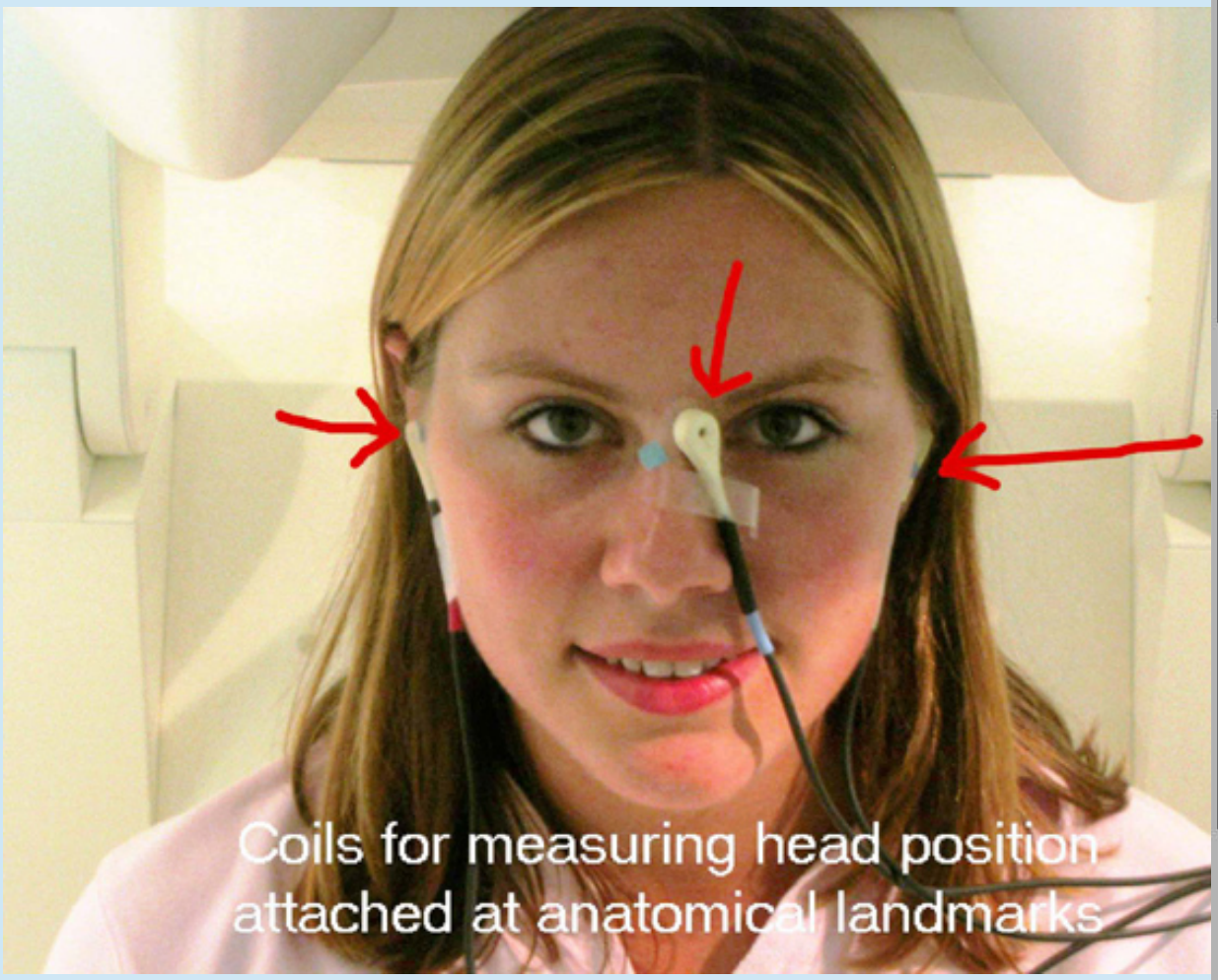


Time-frequency Analysis

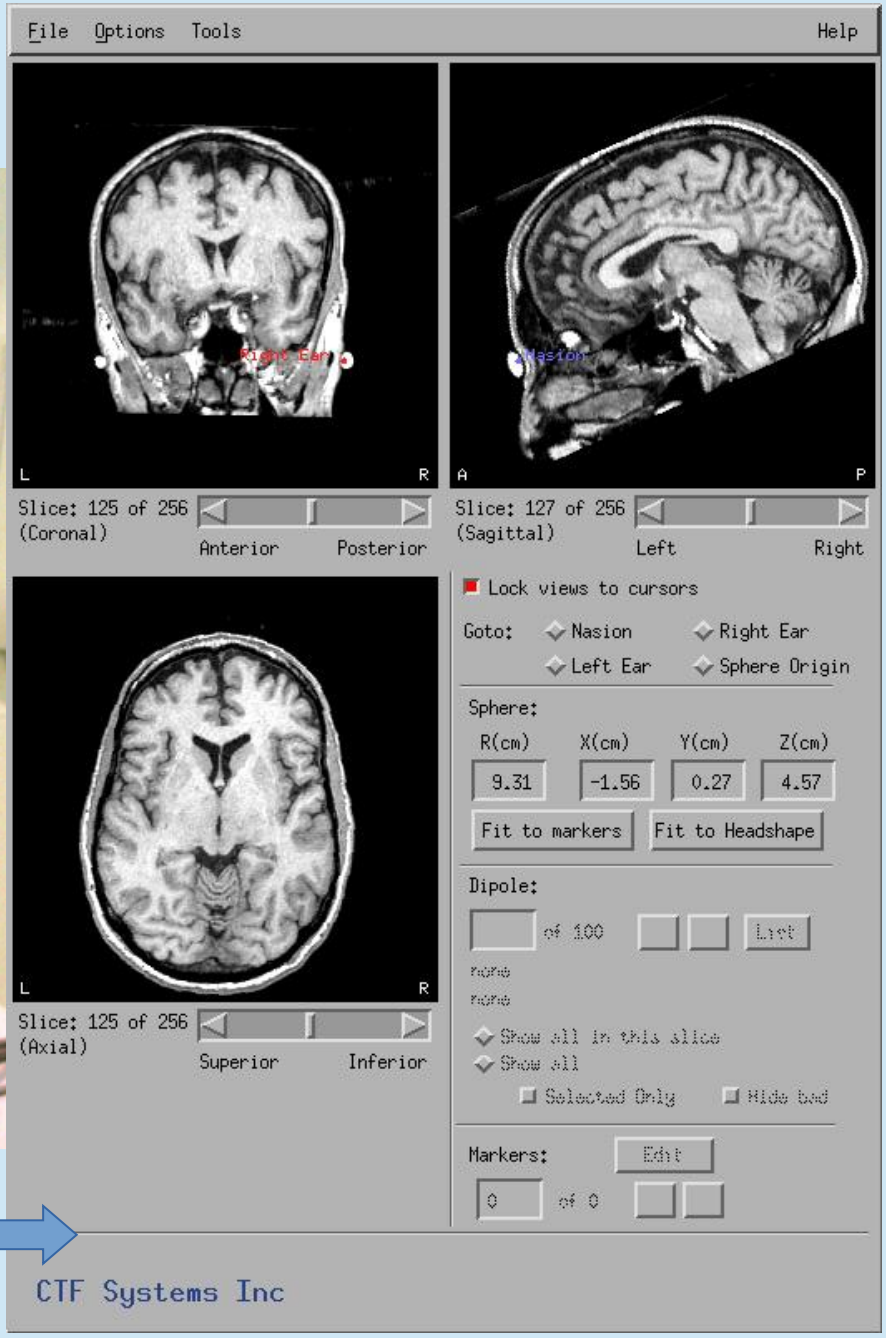


Evoked Response to series of five clicks separated by 250ms

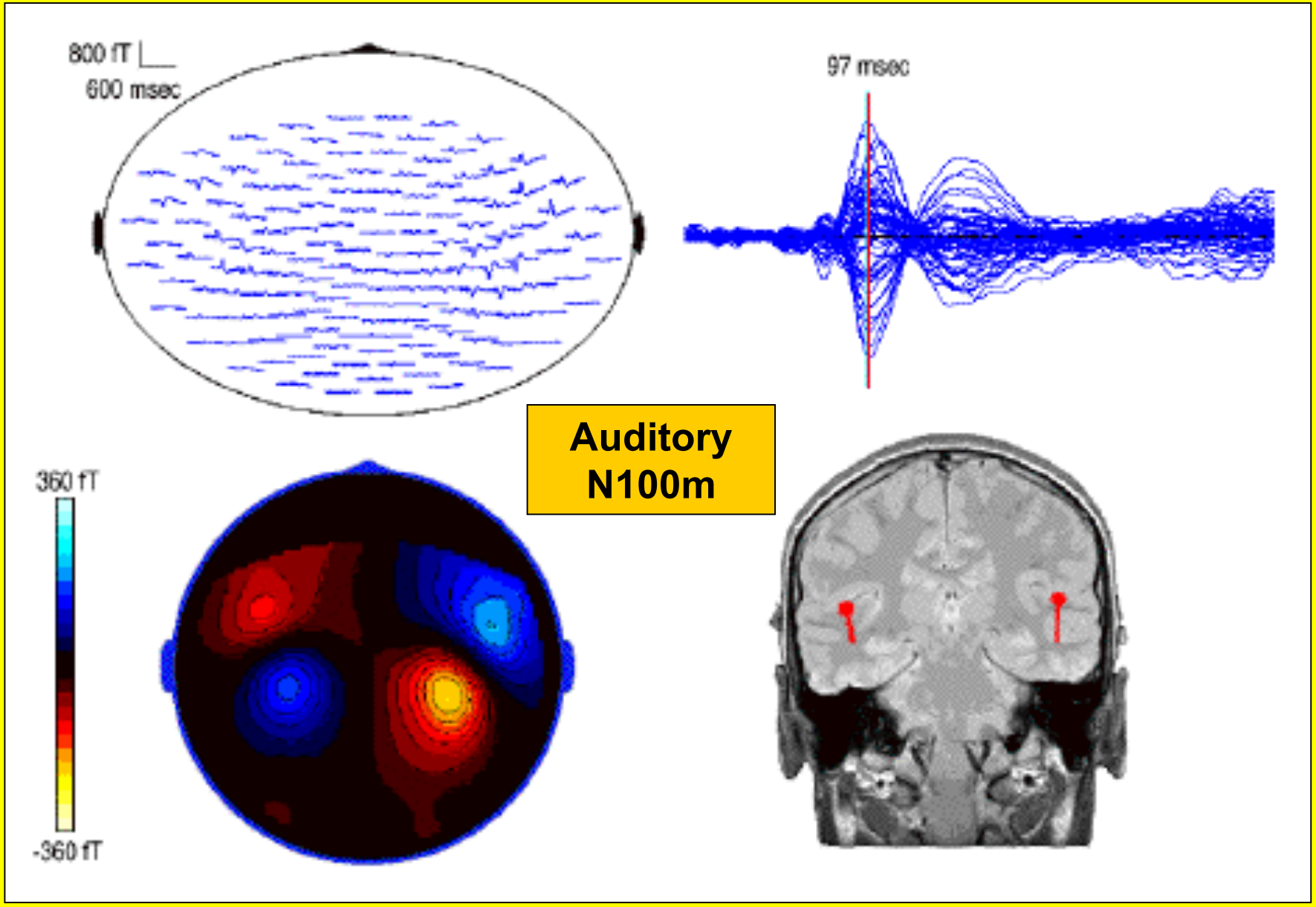
How do we estimate the source of the MEG signals?



The coil locations are then marked on an MRI for co-registration



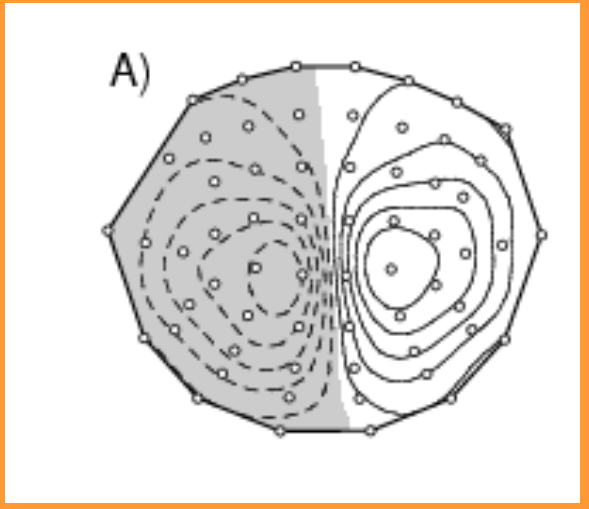
Dipole Fit



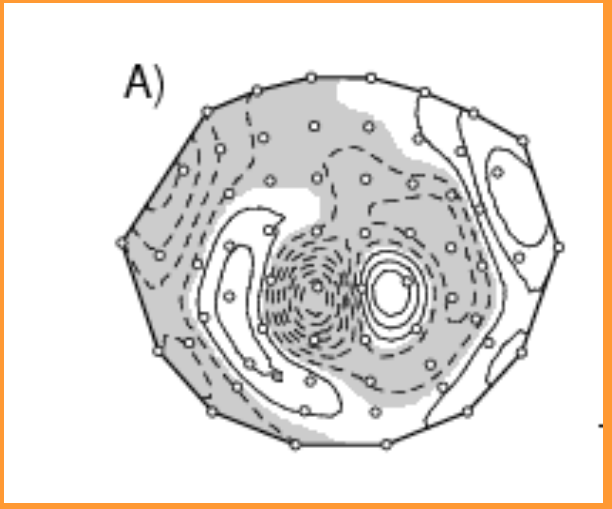
Find the one or more sources that best fit data at single time point

SAM (Synthetic Aperture Magnetometry)

- Produces whole brain estimates of source power for specified time window and frequency band
- Creates a spatial filter (beamformer) for each voxel to block out activity from other locations
  - Not good for correlated sources
  - Can generate ‘virtual channels’ at each voxel
- Subject group analysis can be conducted with AFNI or other fMRI software

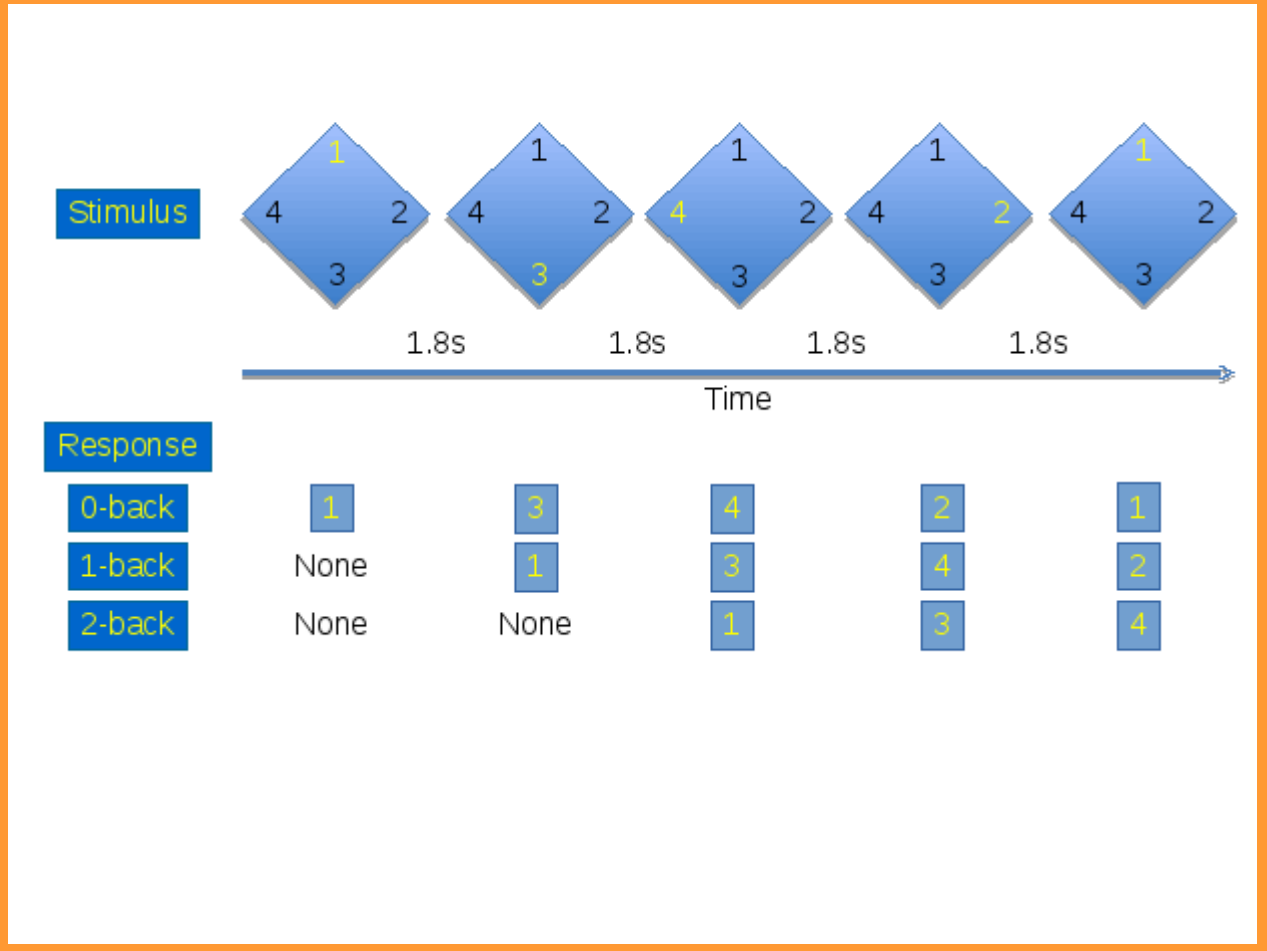


Projection or Source onto Sensors

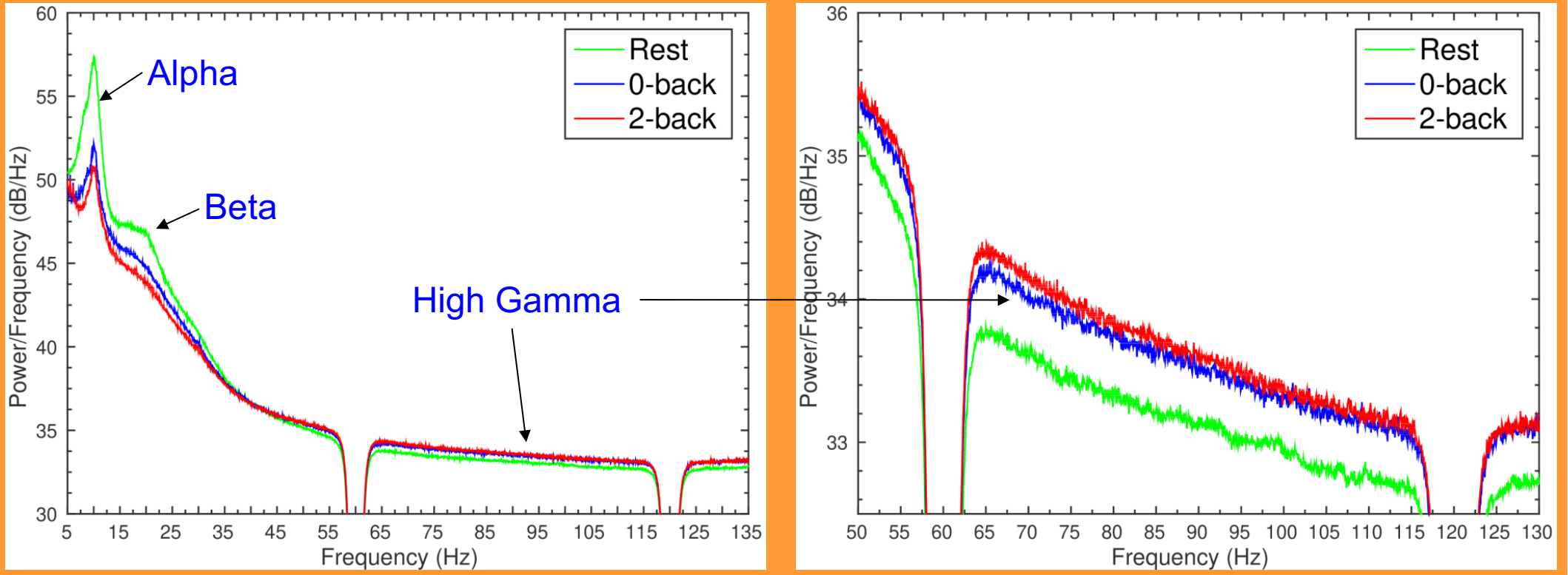


Spatial Filter

Example of SAM Analysis for an N-back working memory task with resting data used as a baseline



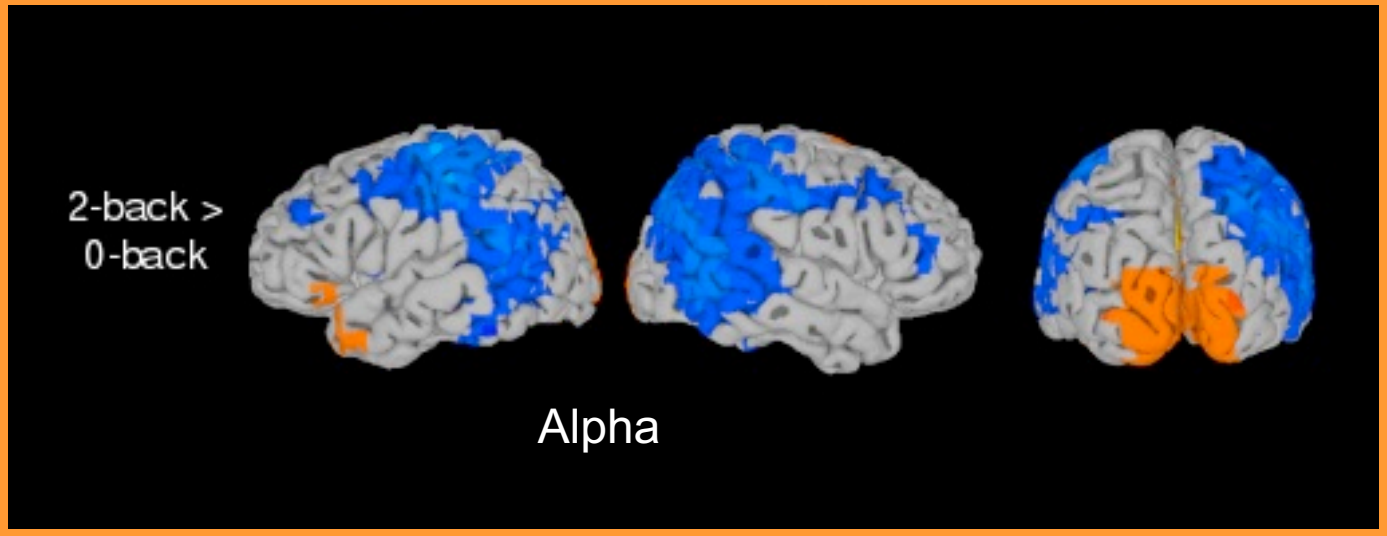
Power Spectra used to determine frequency bands for SAM Analysis

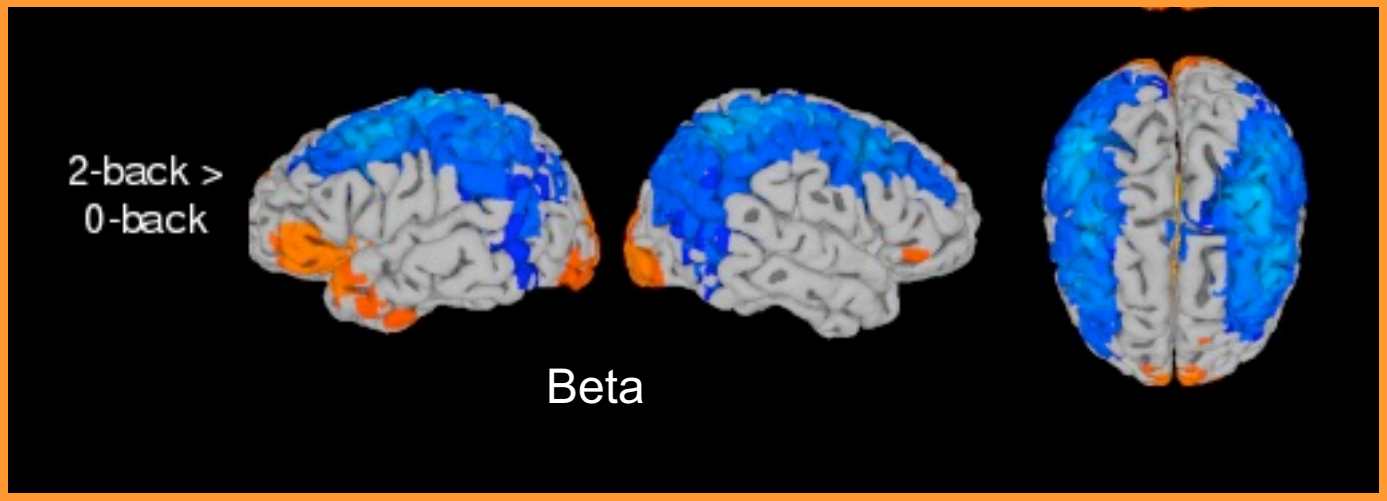


Carver et al., submitted

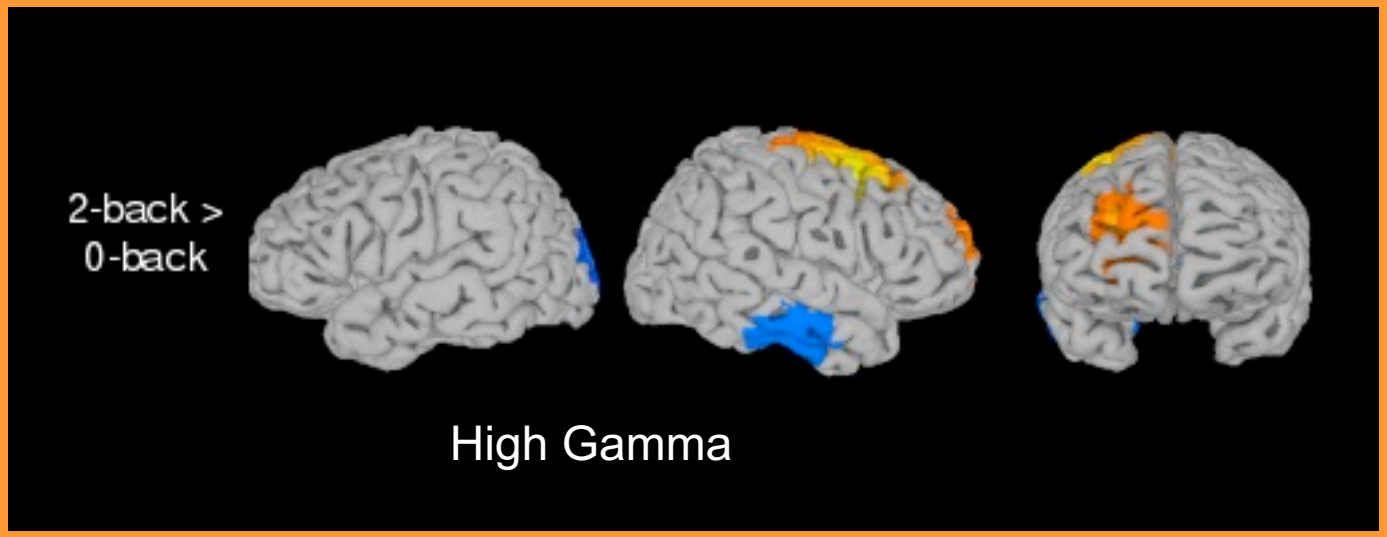
Red = 2 > 0
'synchronization' ?

Blue = 2 < 0
'desynchronization' ?



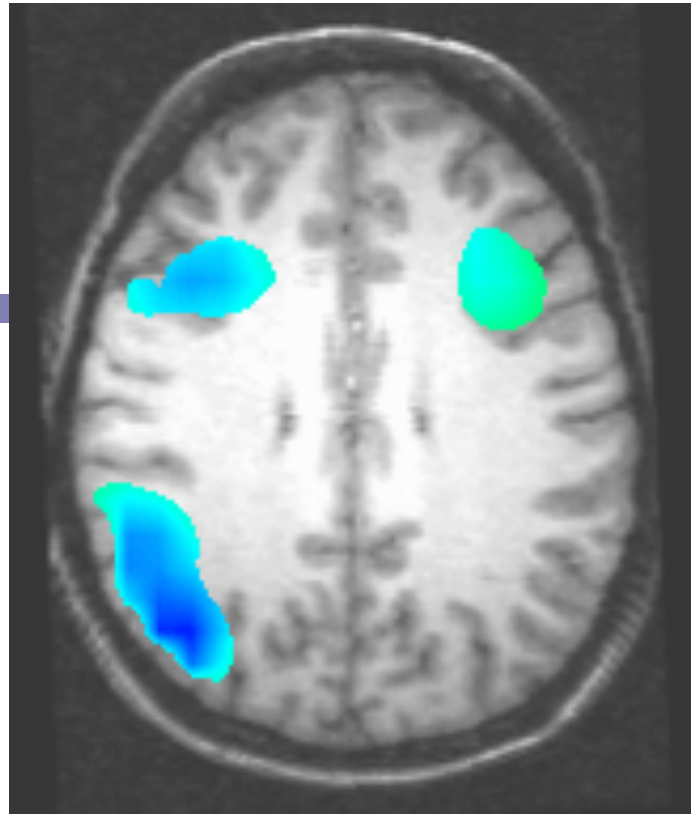


High Gamma =
Spiking?

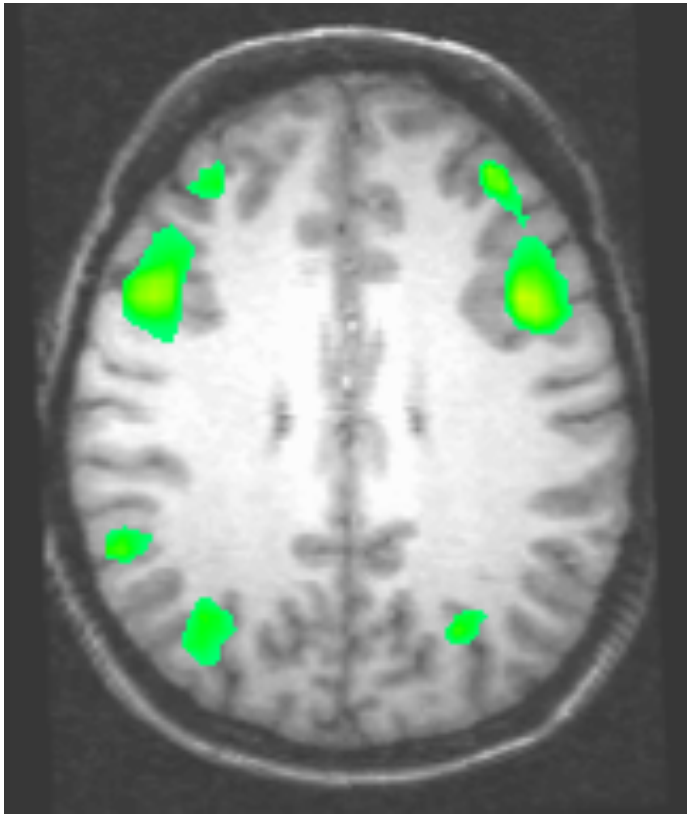


MEG and fMRI

2-back vs 0-back, same 12 subjects

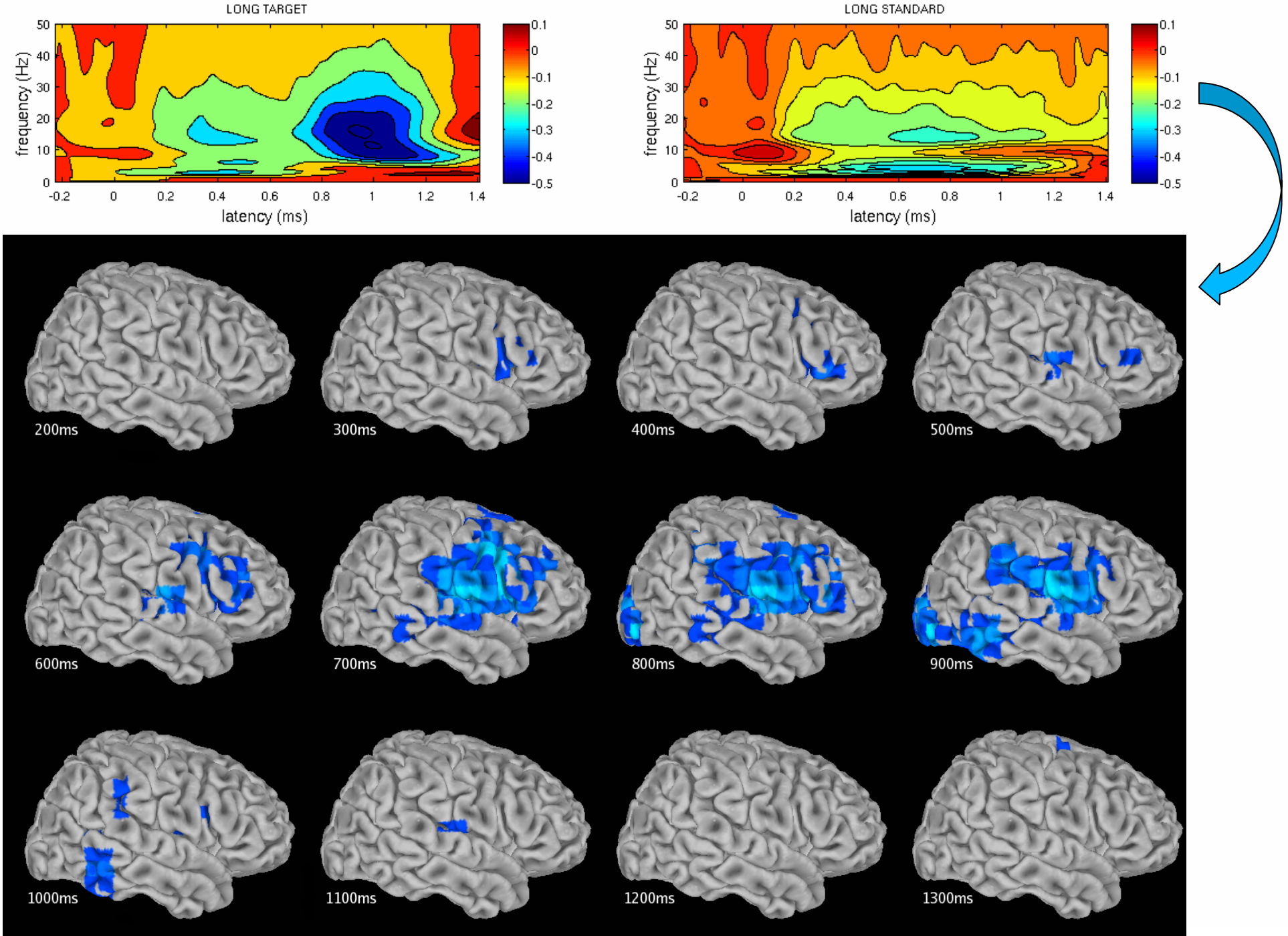


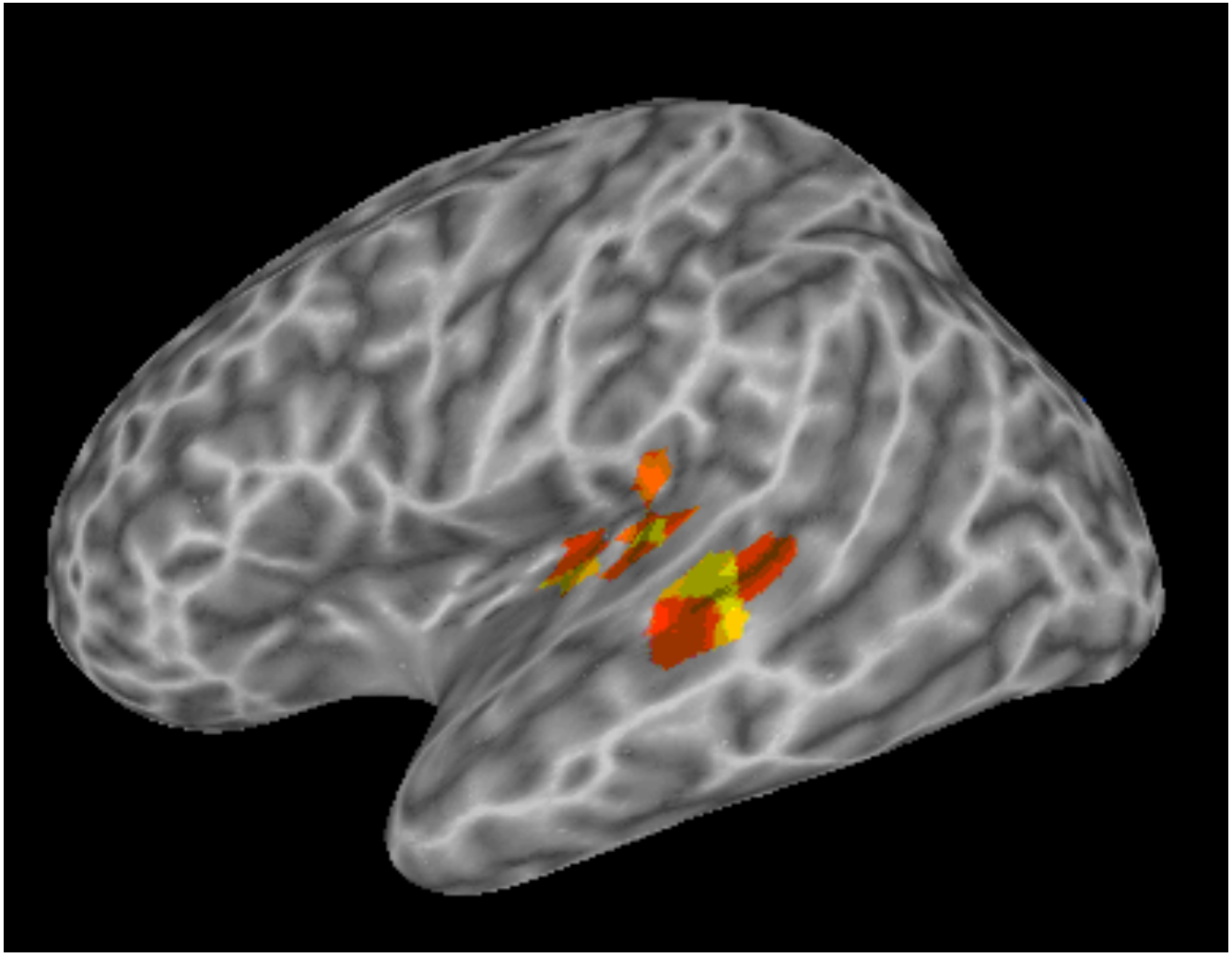
SAM, 500 msec window centered on response, Beta desynchronization



SPM T map 2b>0b {SPM99 t ~ 4.0; $Z_{\equiv}$ ~ 3.10, p ~0.001, k > 10}

Localization not as precise as fMRI, but enhanced temporal resolution. Example from a tone duration experiment



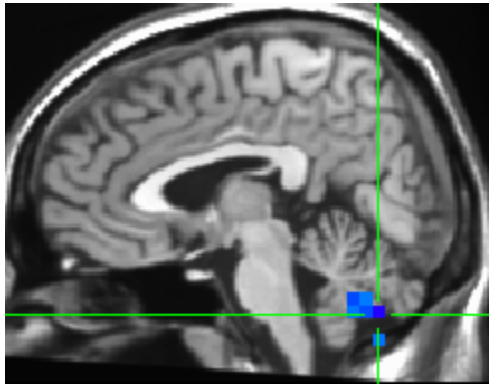


Long non-target tone, < 2s in a loop

Carver et al., 2012

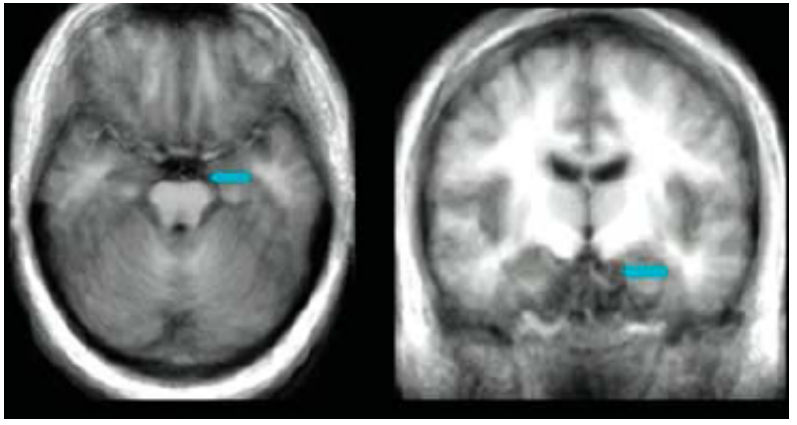
Deep Sources

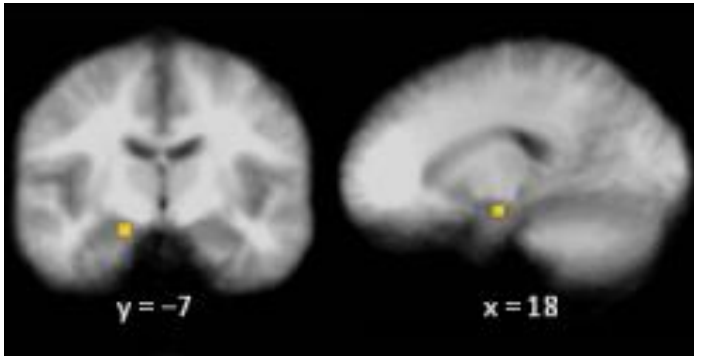
Long deemed to be impossible to observe, but really just a matter of signal-to-noise. Modern MEG systems make it possible.



Cerebellum

Amygdala

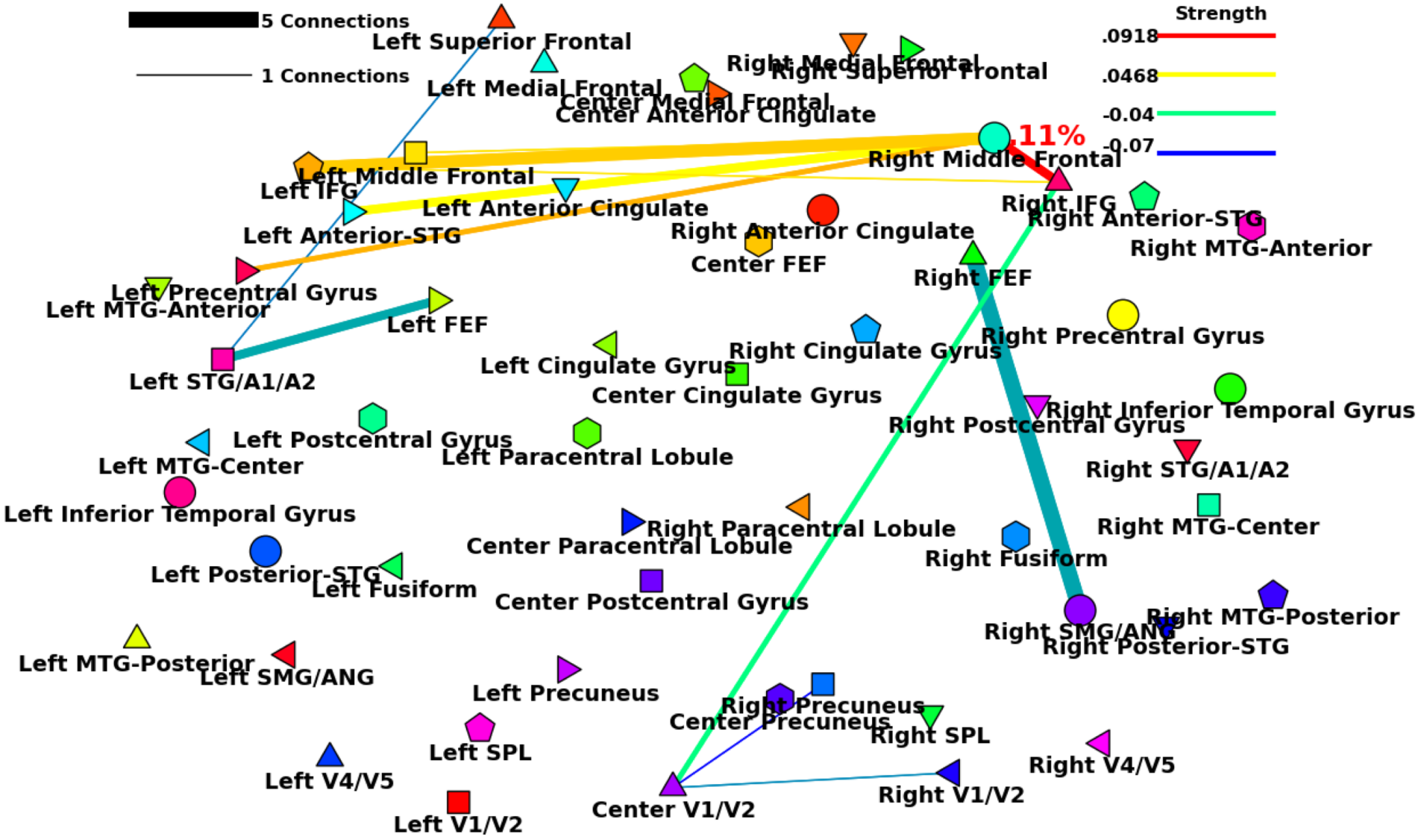




Hippocampus

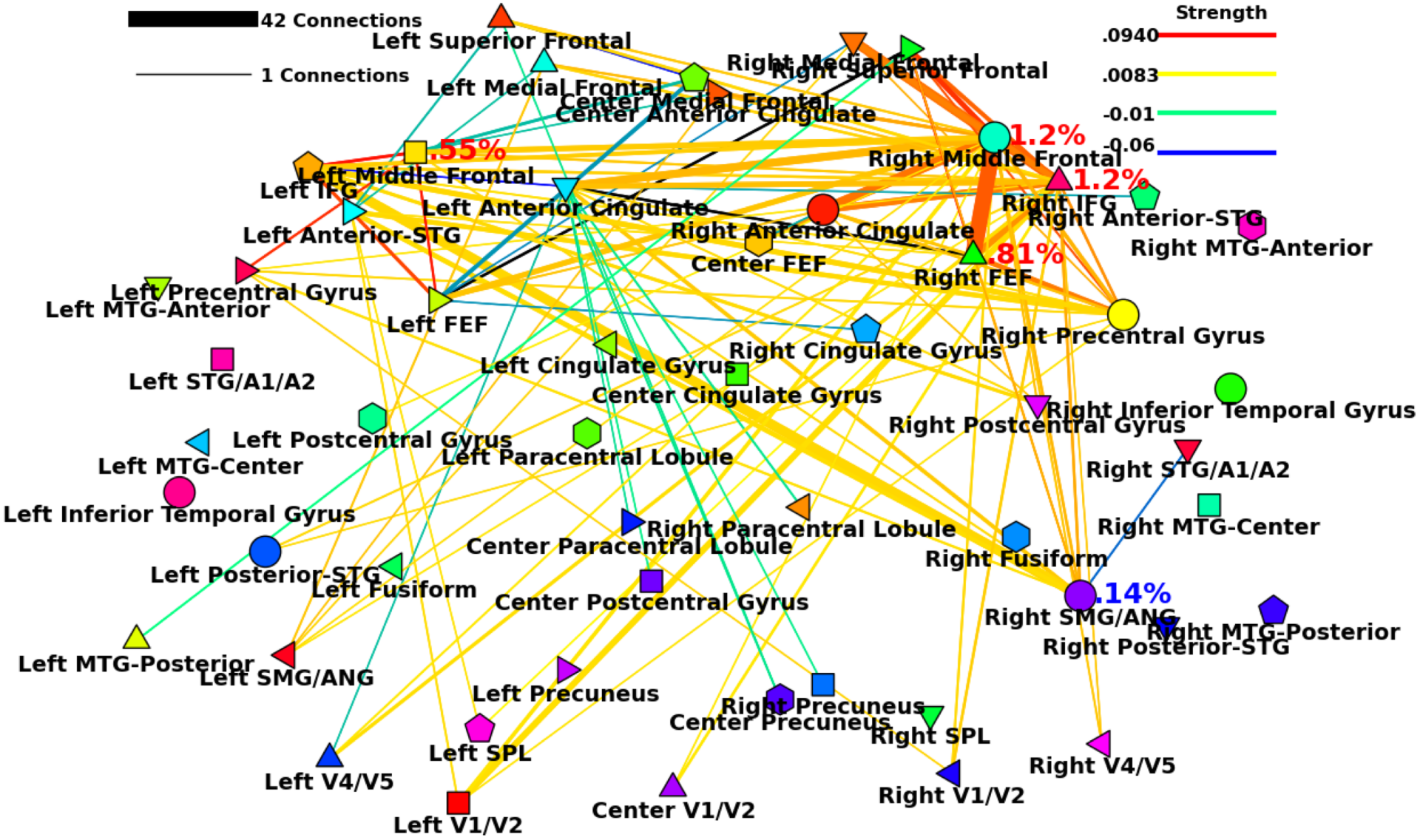
Connectivity?

- as yet no predominant method or theoretical underpinning



Power envelope correlation on virtual channels, N-back

– Tyler Ard dissertation



Coherence, same data

Terminology

Magnetometer / Gradiometer (axial/radial/planar)

Channel

Time series

Topograph

Evoked field

Event-related field

Induced activity

Frequency band

Power / Amplitude / Phase

Power spectrum / Time-frequency plot

Synchronization / Desynchronization

Dipole (ECD)

Spatial filter / Beamformer

Sensor space / source space

Virtual channel

Covariance / Correlation / Coherence

Thank You!

email: carverf@nih.gov
website: megcore.nih.gov
listserv: MEG_ANNOUNCE

Coming Attractions!
Club MEG