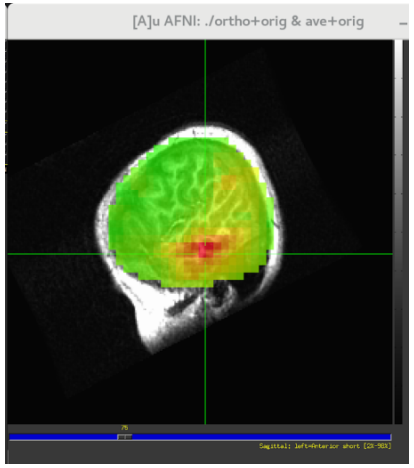
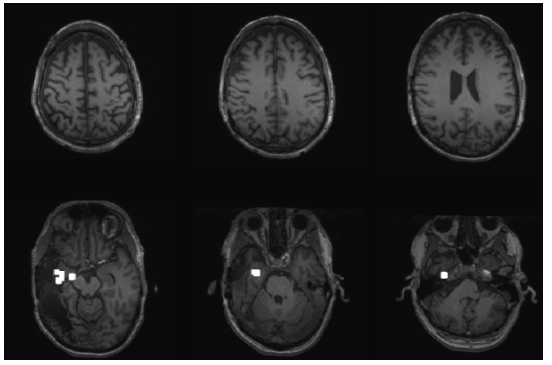
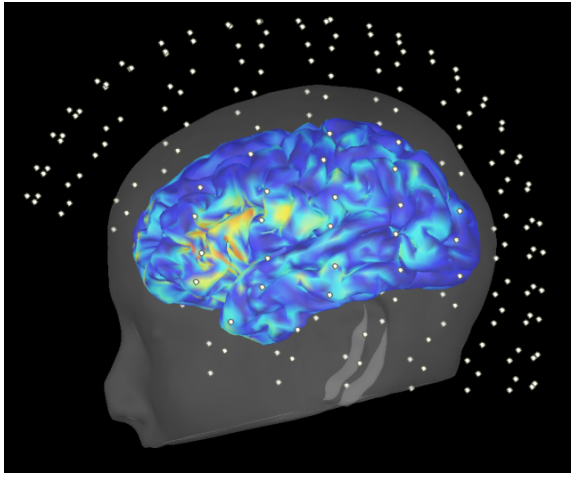


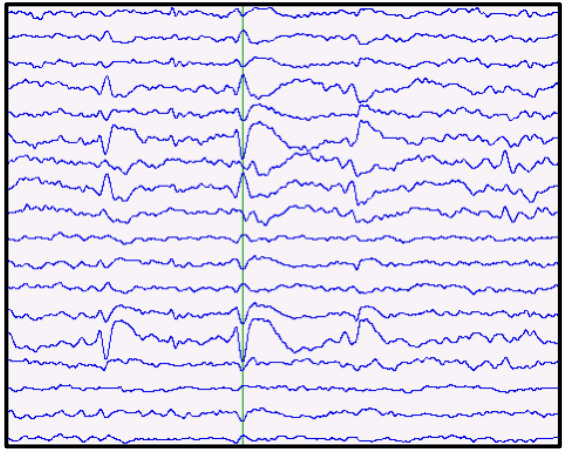

2023 GW
Epilepsy Board Review
& Best Practices



# Fundamentals of Magnetoencephalography in Clinical Epilepsy



Jeffrey Stout, PhD
NIMH MEGCore



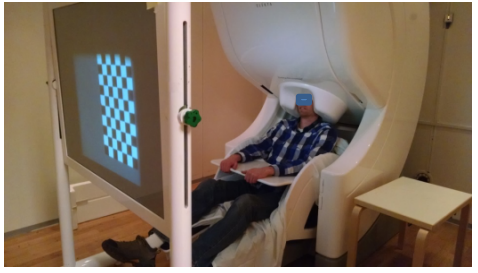
# Outline

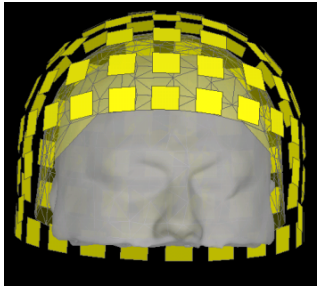
- Basics overview
- MEG Physics
- Comparison with EEG
- Incorporating MRI with MEG
  - Source localization
- Epilepsy Examples
- Functional localization examples

# Basics of  Magnetoencephalography (MEG)

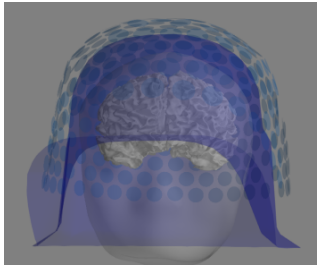
- MEG is a neurophysiological technique similar to EEG
  - Based on magnetic fields (vs electrical voltages for EEG)
  - Fixed array of 200-300 channels

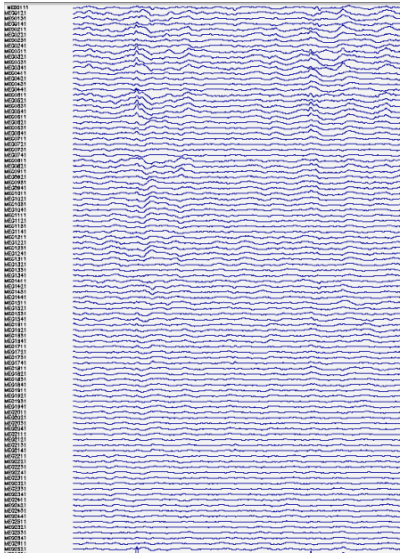
Subject in Scanner





Sensors relative to head

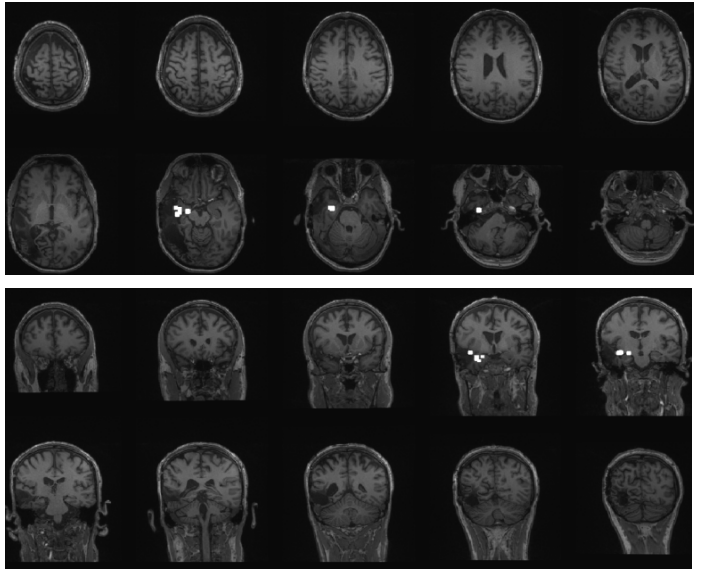




MEG Recording

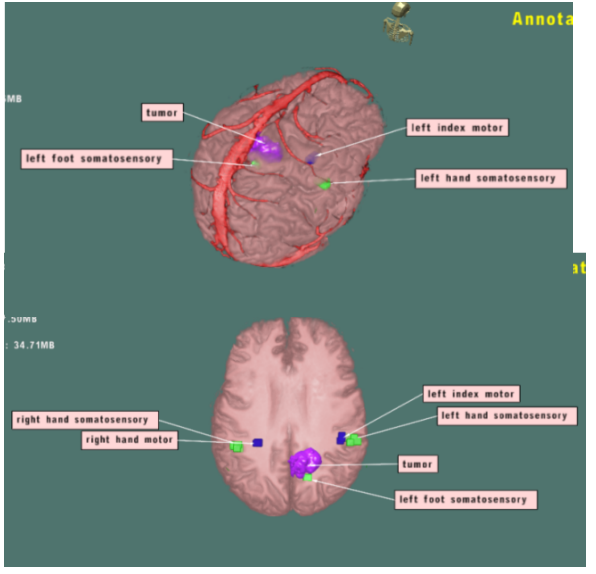
# Uses for Clinical Epilepsy

- Localization of epileptiform discharges for pre-surgical workup
- Localization of functional cortex to identify functional reorganization



Epileptiform spike localization (each dot is a spike localized)

Functional cortex localization relative to tumor



# Magnetoencephalography (MEG) Sensor

Elekta Neuromag System

*Seated – Evoked Task*

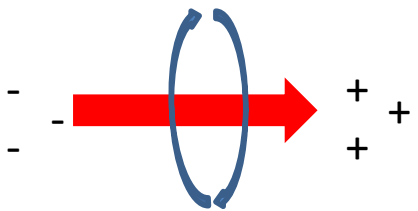
*Supine – Spontaneous Epileptiform*

CTF System (NIH)

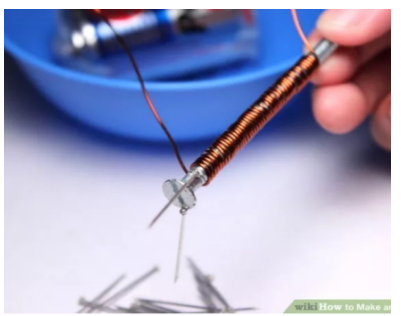
4D System

*Supine*

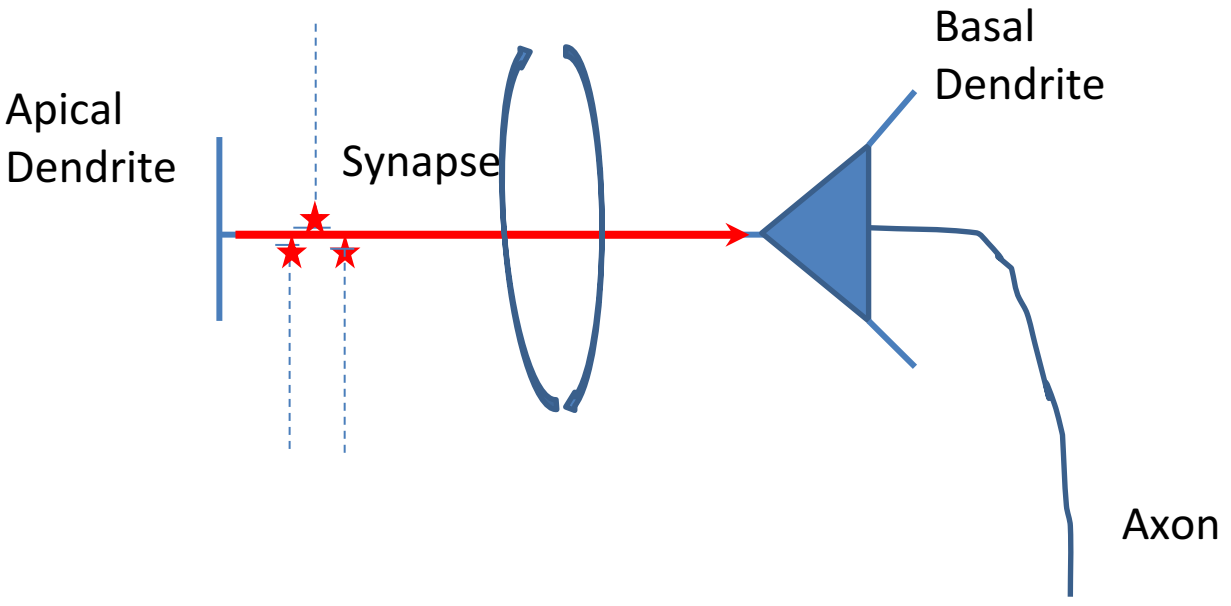
# Physics
# Currents Produce Magnetic Fields




Electromagnets can produce magnetic fields using electric currents

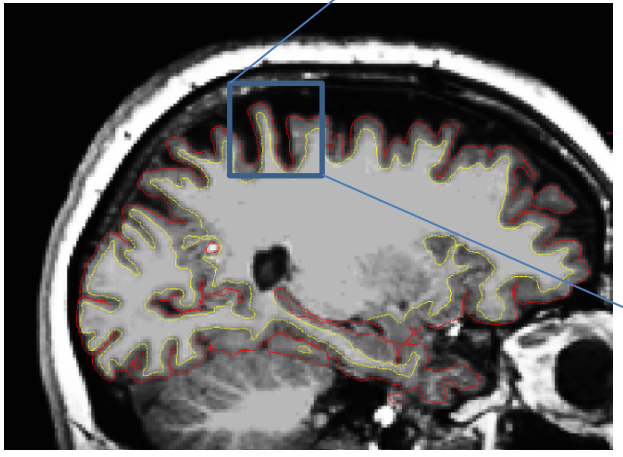


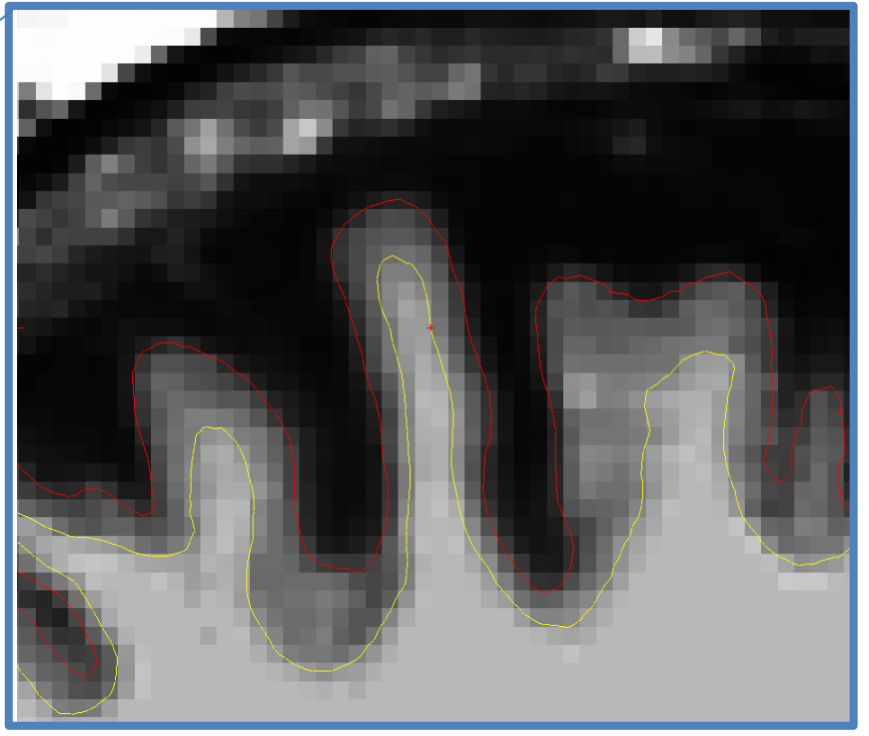
# Dendrites conduct intracellular currents that produce magnetic fields



# Brain Structure

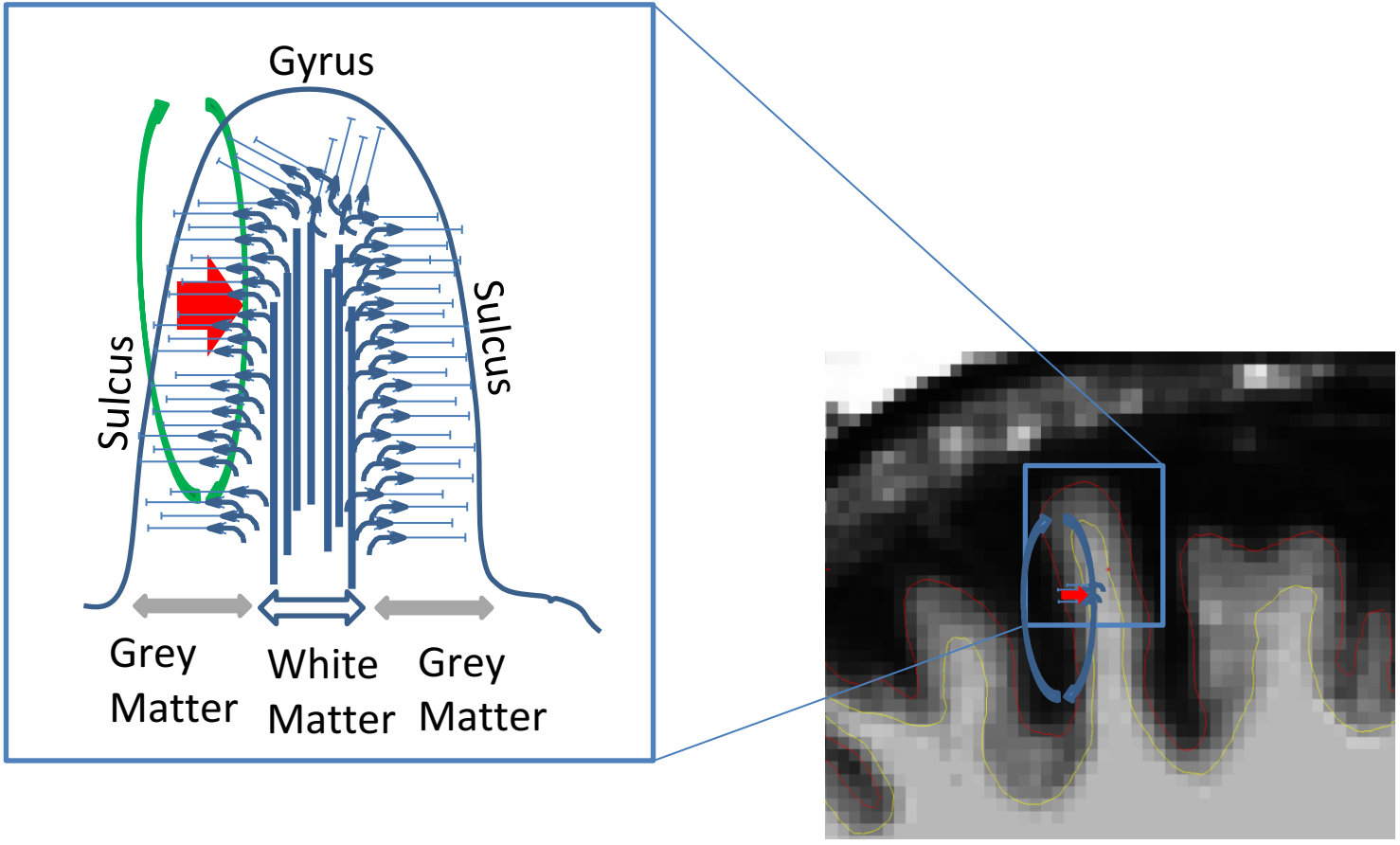
Sagittal Cut MRI



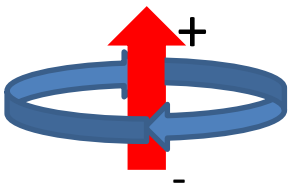


CSF / Grey Matter Boundary (RED)
Grey Matter / White Matter Boundary (Yellow)

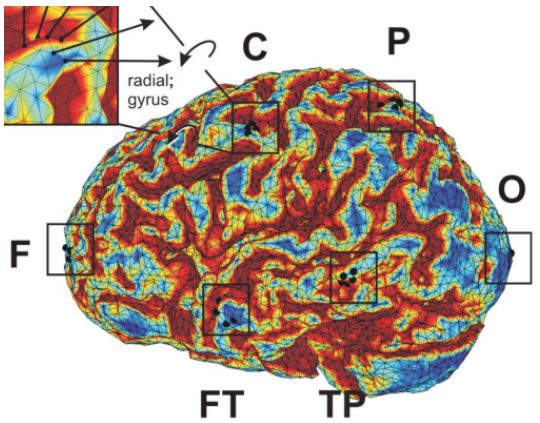
# Physics
# Brain Current Produce Magnetic Field

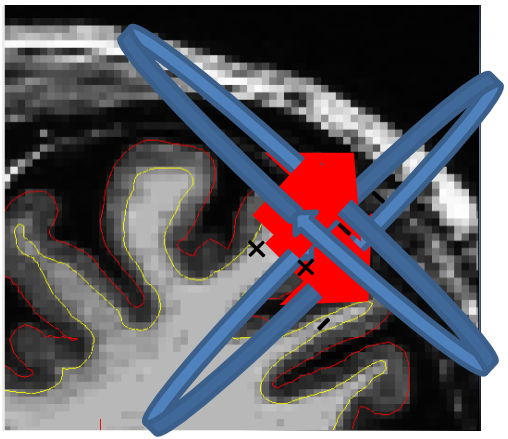


# Radial vs. Tangential Activity




Current (red)
Magnetic Field
(blue)



Tangential Cortical Activity allows magnetic fields to be picked up by MEG sensors

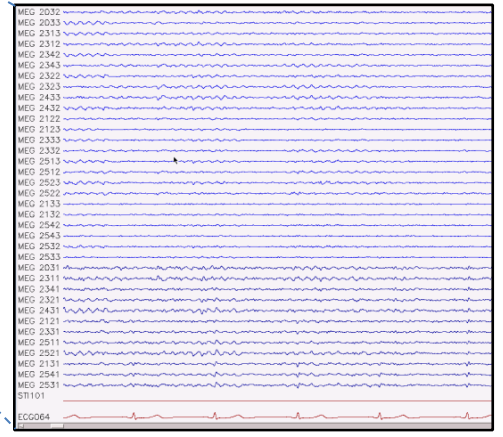
Cortical areas in red have a preferential orientation for MEG[1].
Areas in blue have a preferred orientation for EEG. (EEG can also see areas in red, but are less sensitive)

1) Haueisen et al. 'Tangential and Radial Epileptic Spike Activity: Different Sensitivity in EEG and MEG'. *Journal of Clinical Neurophysiology*

# Data Acquisition

Data Acquisition Terminal:
Camera and Intercom for subject monitoring

Subject in scanner for recording



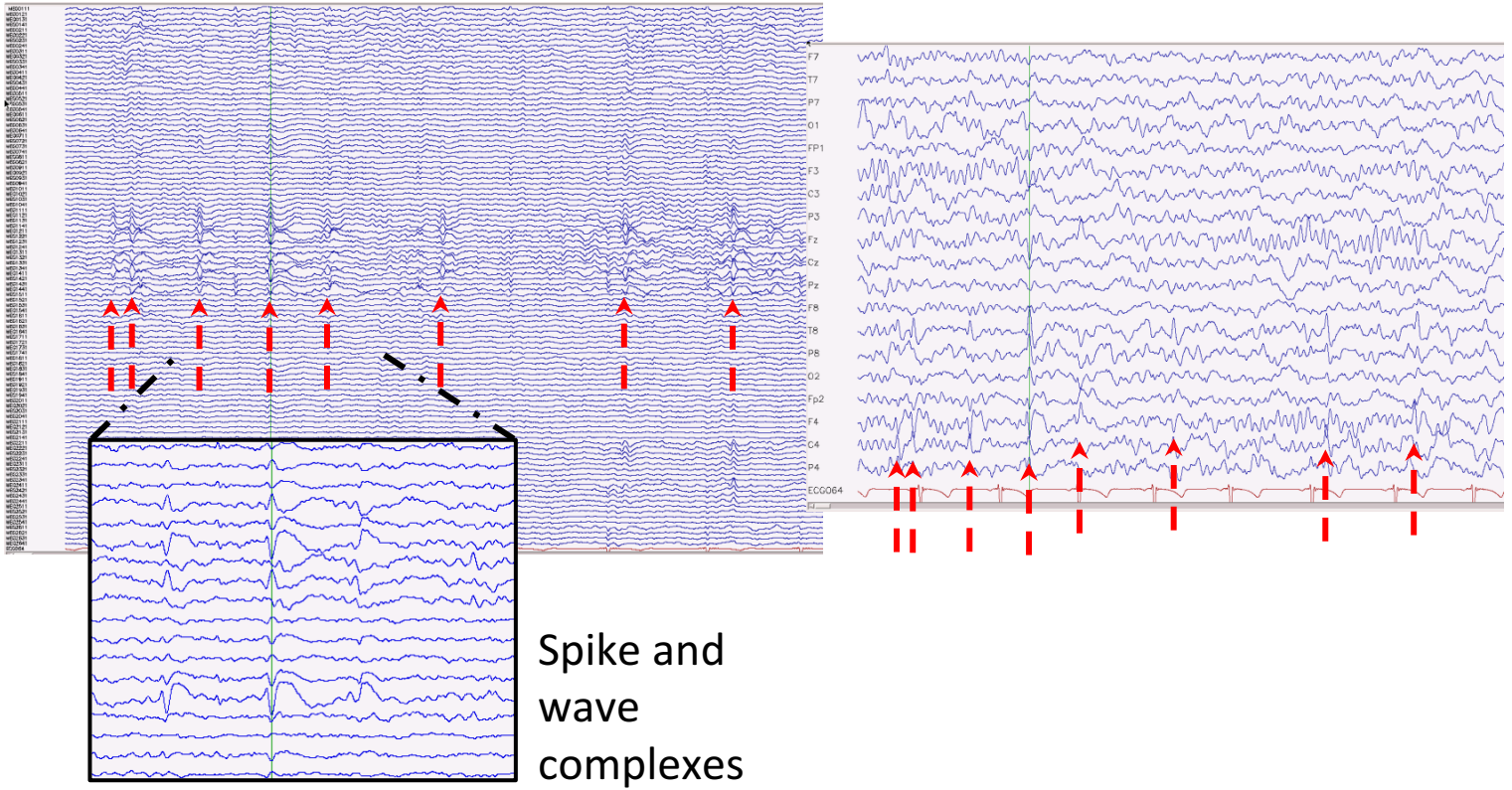
Live Review of the data to assess data quality

# MEG signals versus EEG

Concurrent MEG/EEG recording

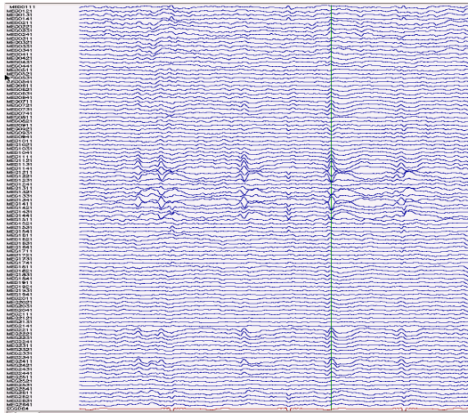
**MEG (102/306 Channels)**

**EEG (19/22 channels)**

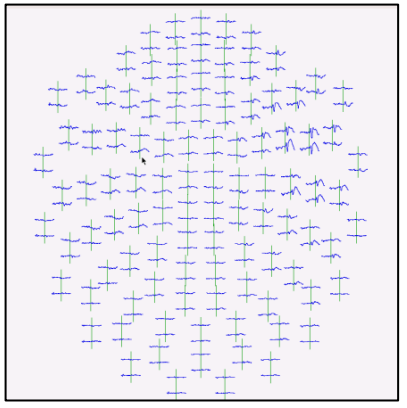



Spike and wave complexes

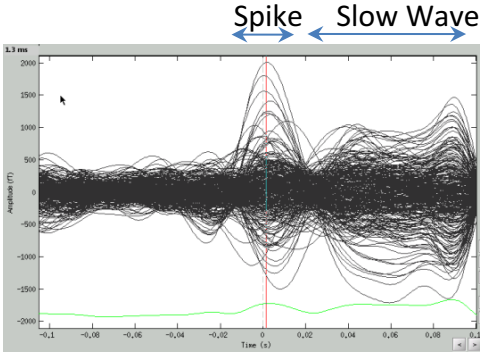
# MEG Sensor Displays



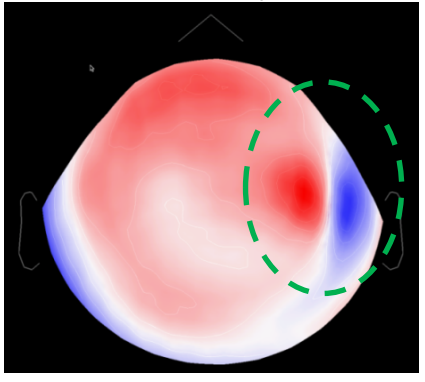
Scrolling Time Series
(Review of data)



Sensor View
(Coarse Localization)




Butterfly Plot
(Fine Tune Timing)

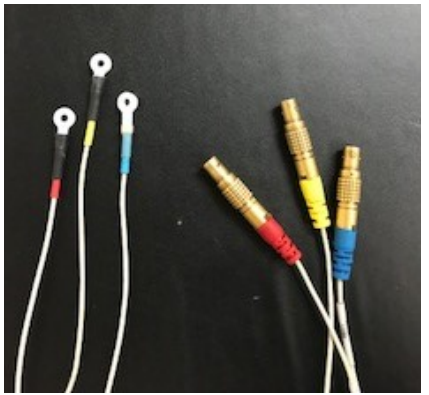


Spike Topography and Orientation

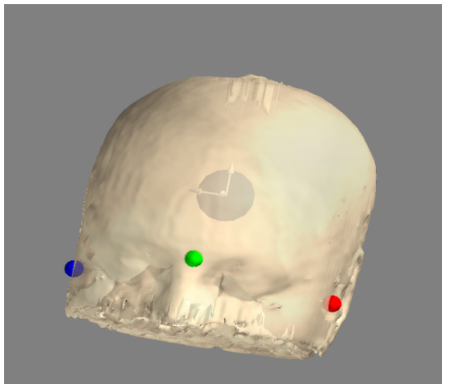
To map MEG data to the brain we must incorporate an MRI

# MEG Coregistration to MRI

- Fiducial Coils are taped to locations on the head
- The same positions are identified on MRI (below)

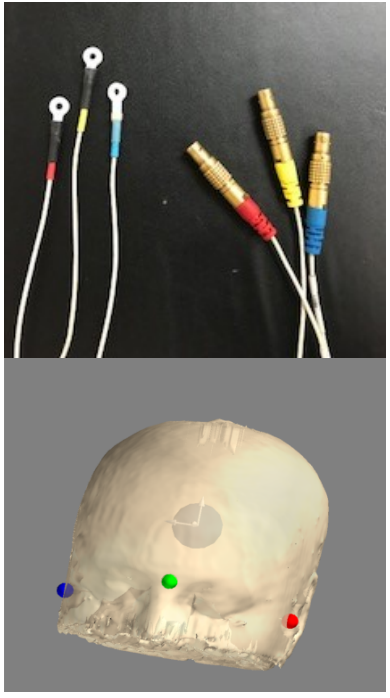



Fiducial Coils

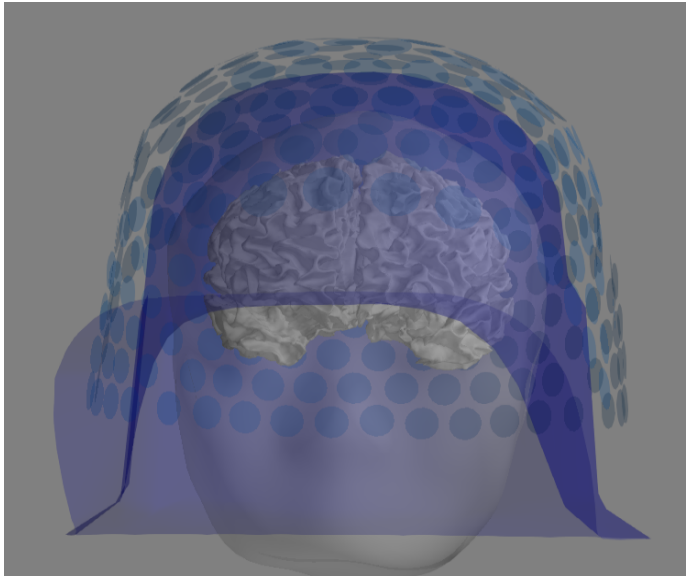


Coils Mapped to MRI

# MEG Coregistration to MRI



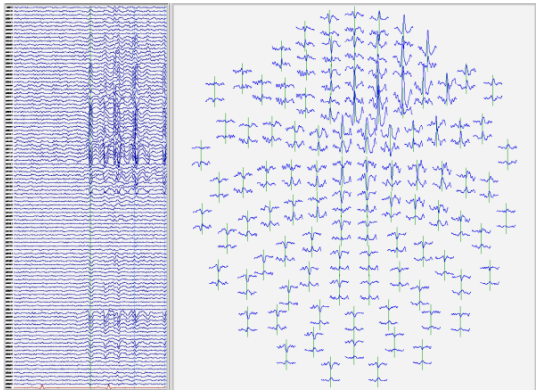
- At the beginning of the run the coils are temporarily activated
- Active coils are then localized in the helmet
- The localization of the coils to the MRI and MEG allow for the brain to be **coregistered** between the modalities
- The sensitivity of the channels can now be mapped to brain regions

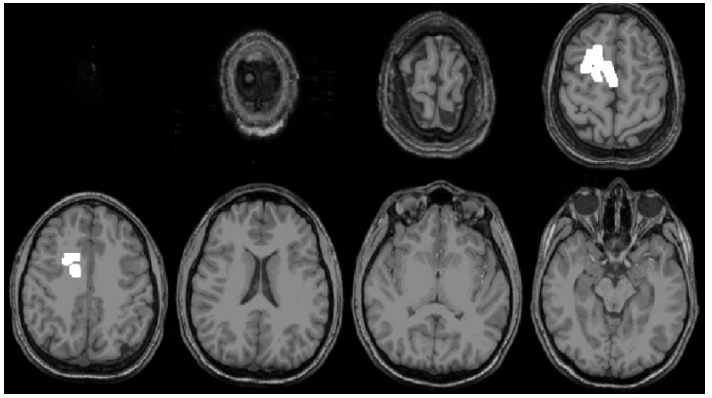


Head / MRI localized in the MEG during the run

# MEG Source Localization – Inverse Model

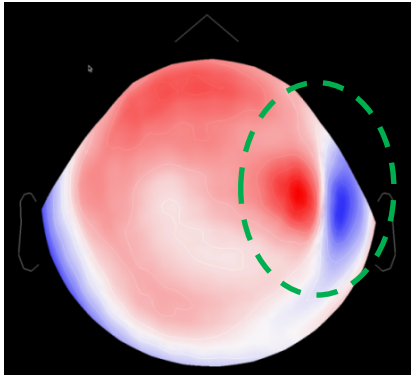
Example 1



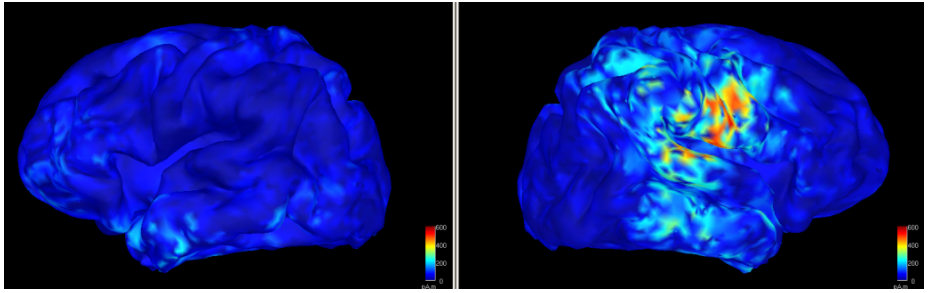


Single Dipole localization (multiple spikes – white dots)

Example 2
Different Data

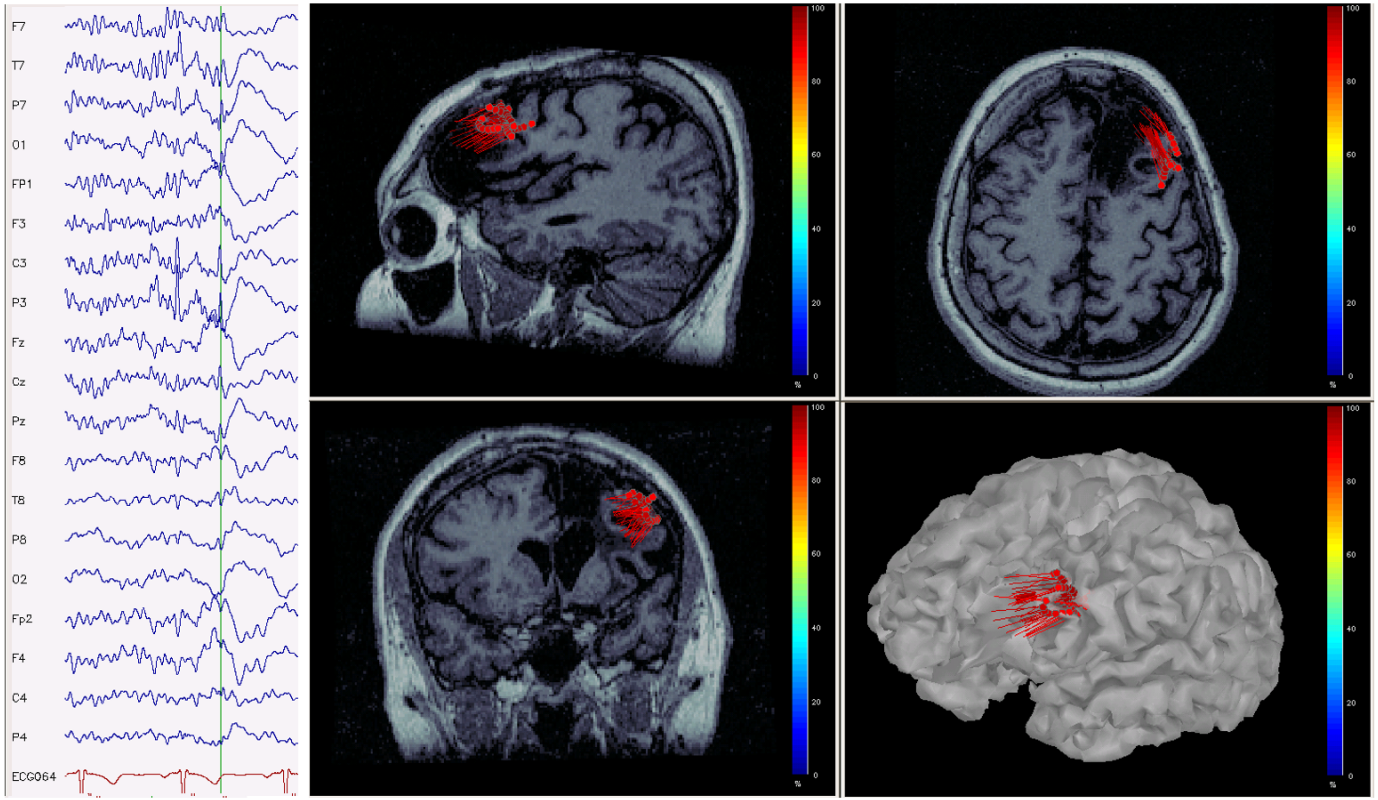


Spike Topography



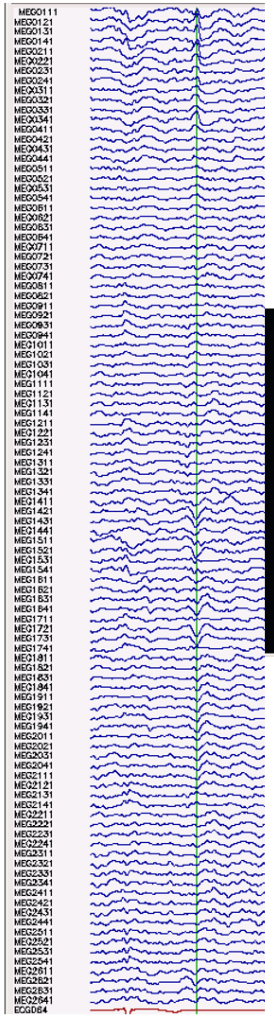
Distributed Model Activation Maps

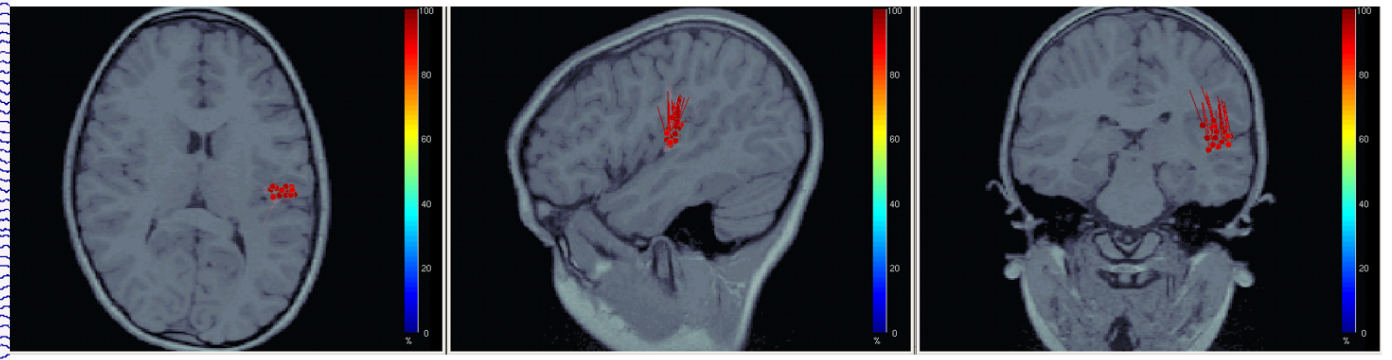
# Tangential dipoles and EEG mislocalization

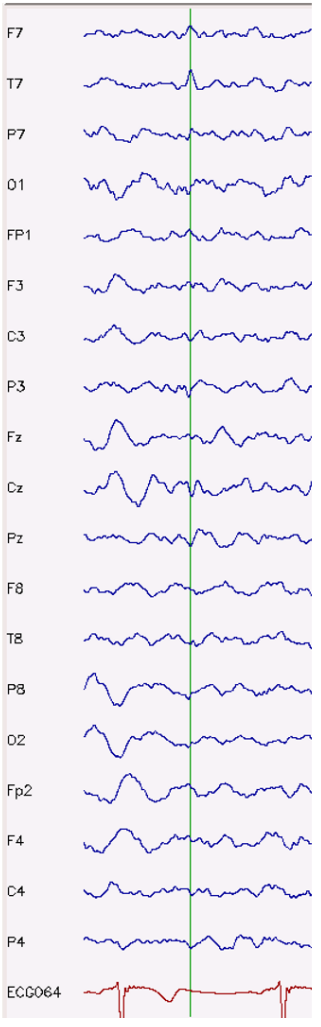



Slide provided by Manoj Raghavan MD, PhD from the Medical College of Wisconsin Adult Epilepsy program.

# Tangential dipoles w/ poor EEG signal







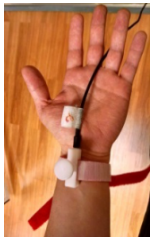

The vertical dipolar sources within the Sylvian fissure account for the weak representation in EEG

Slide provided by Manoj Raghavan MD, PhD from the Medical College of Wisconsin Adult Epilepsy program.

MEG

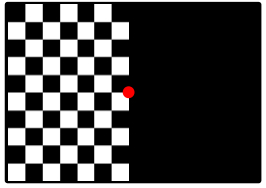
EEG

# Collection of Functional Evoked Data in MEG



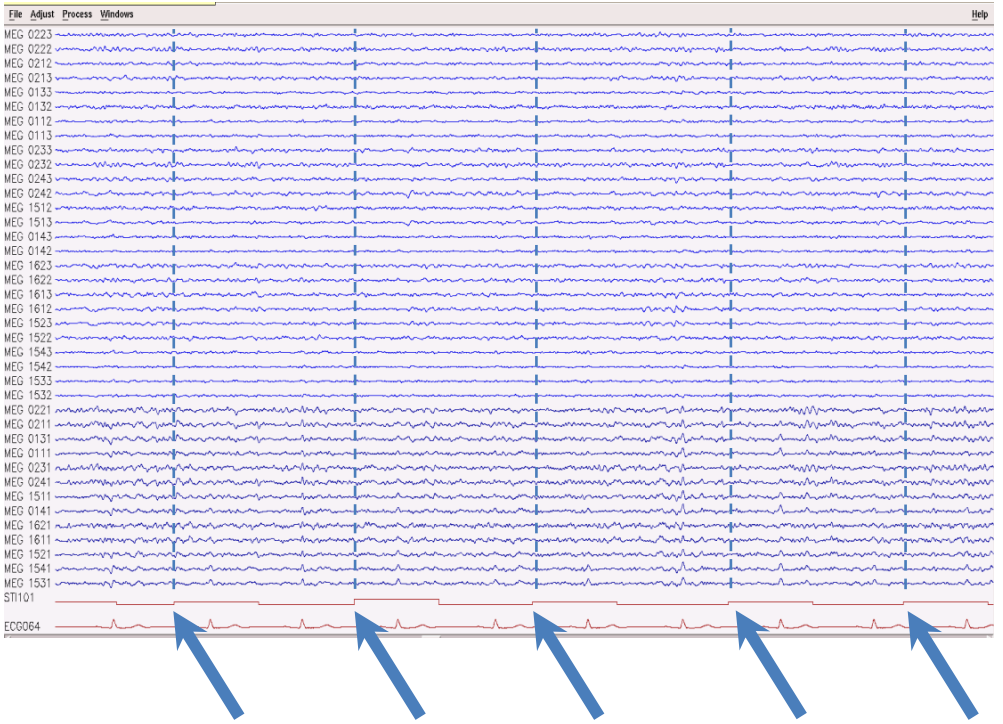
Somatosensory

Auditory



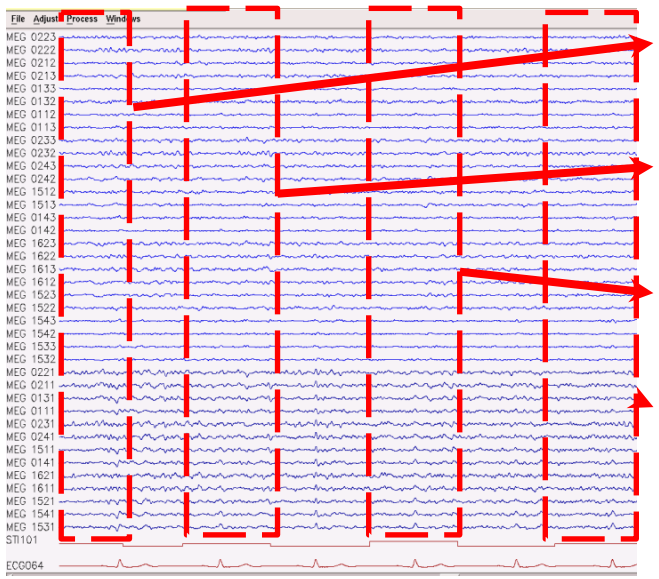
Visual

Continuous data acquisition with concurrent stimulation

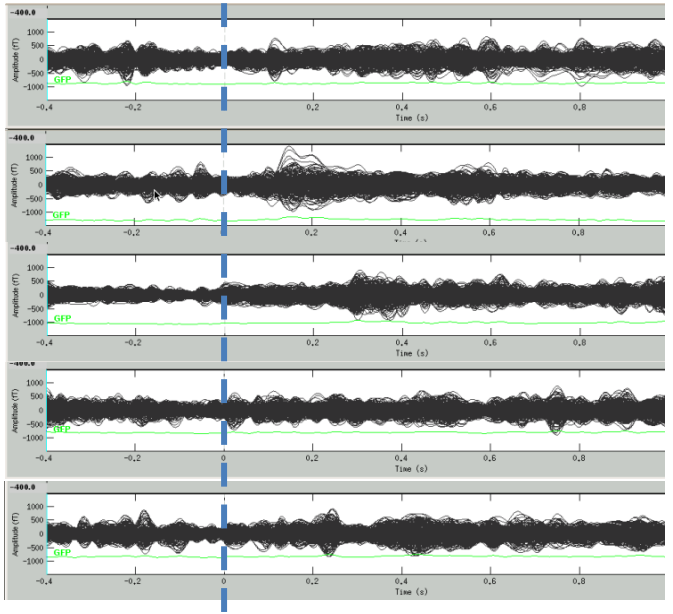



Trials demarked by Stimulus Channel (Top Red Trace)

# Raw Data During Evoked Task

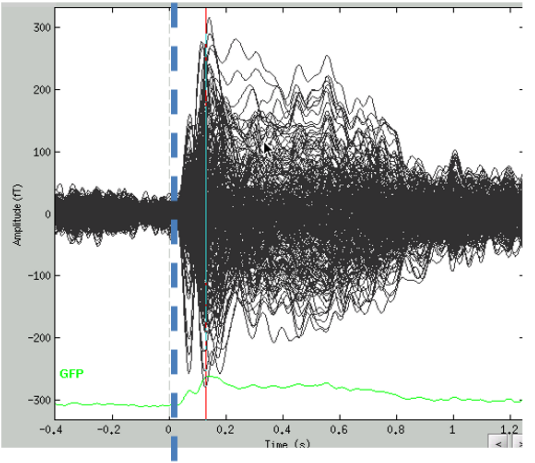



Individual Trials




PreStim PostStim

Averaging trials suppresses background activity

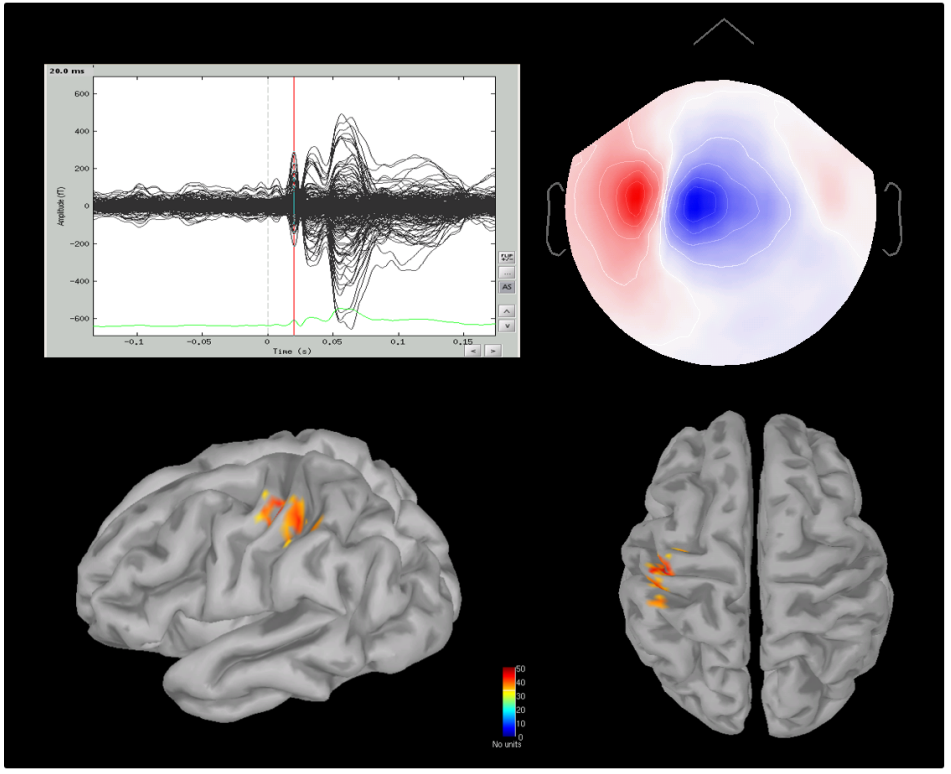



PreStim PostStim

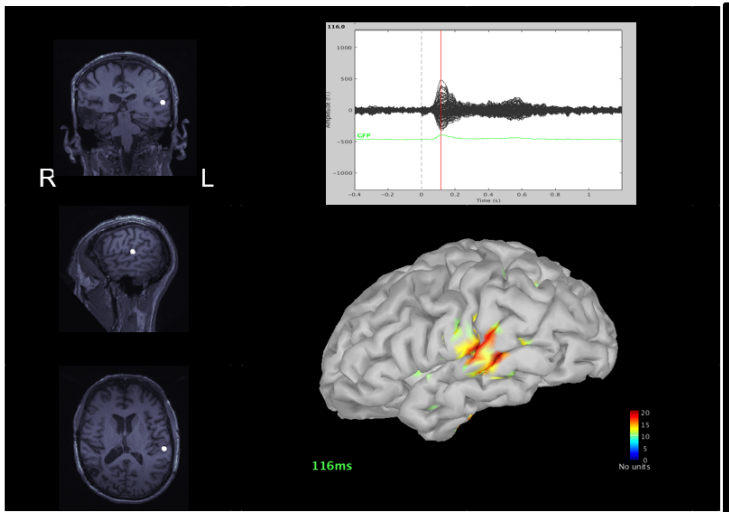
# Somatosensory Evoked Data

Median Nerve Stimulation at the wrist

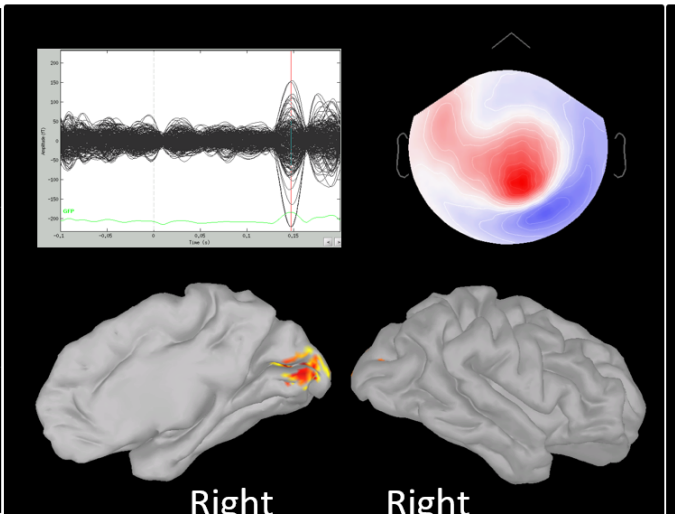
250 events averaged



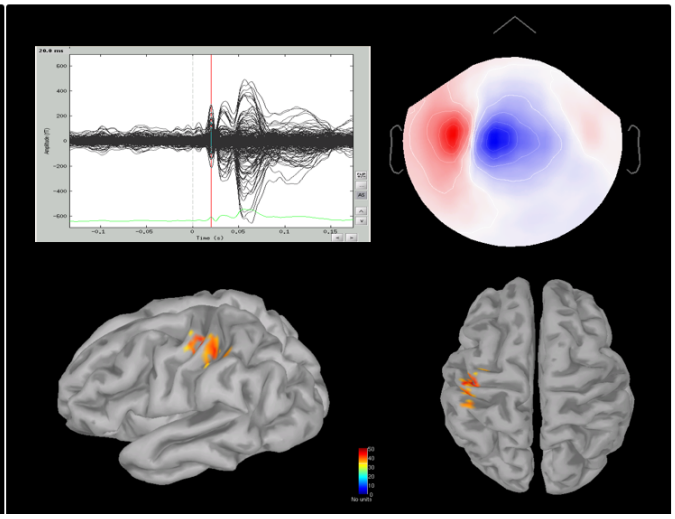
# Primary Sensory Localization Examples




Auditory




Visual



Somatosensory

# Summary

- MEG is a neurophysiological technique that records magnetic fields
- Magnetic fields are primarily generated from post-synaptic dendritic currents
- MEG preferentially sees tangential sources
  - Much of the brain is in the sulcal walls
- Channel level information provides epileptiform discharge identification
- Integration with MRI allows precise localization of the activity
- Epileptiform activity can be localized to identify clusters of activity