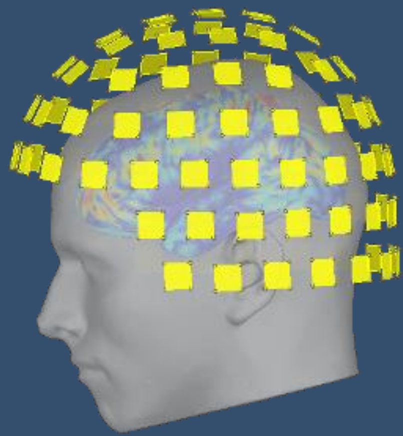
MEG and EEG analysis using Brainstorm 3.2

http://neuroimage.usc.edu/brainstorm



USC University of Southern California

Cleveland Clinic

McGill

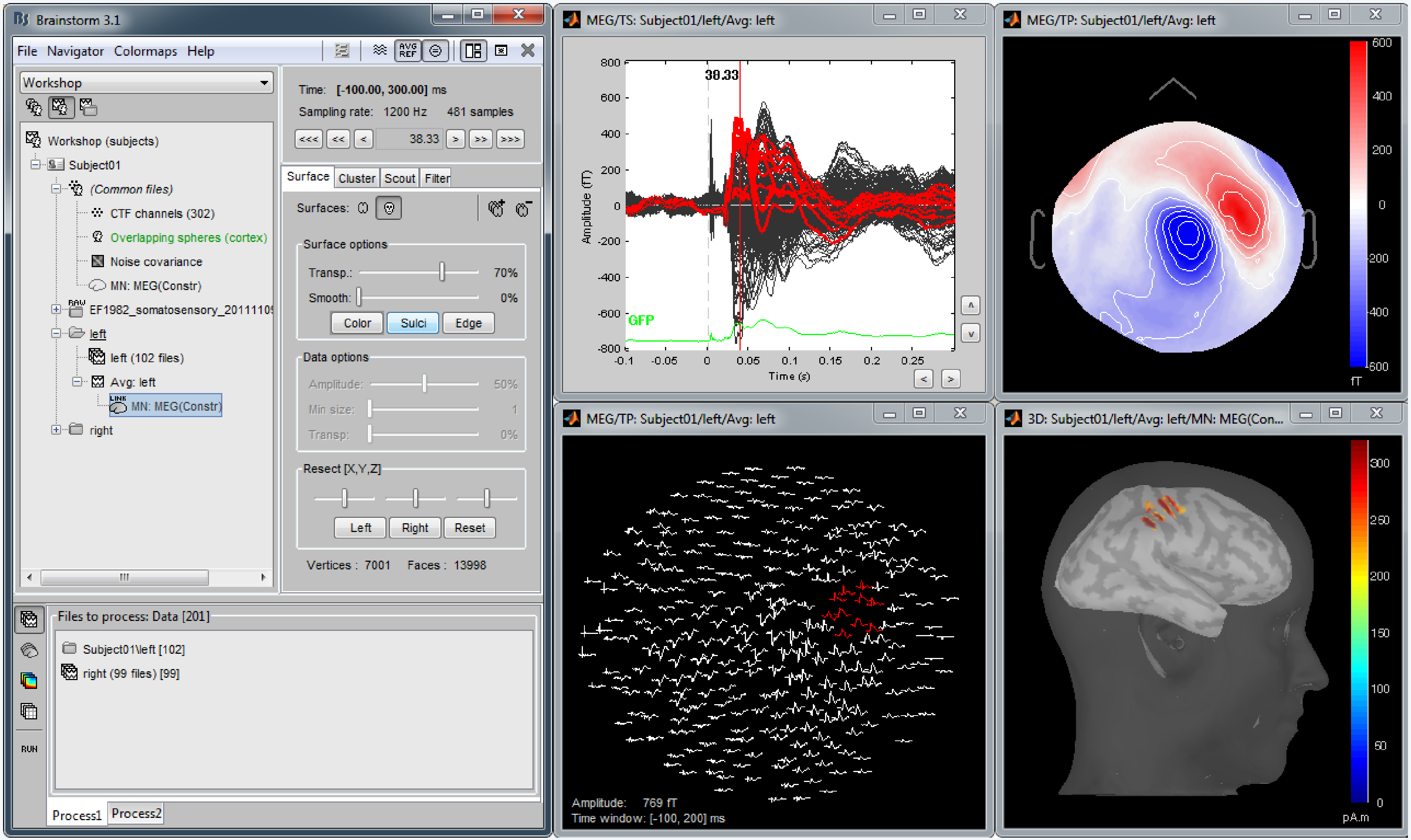
neuro

François Tadel & Sylvain Baillet

May 2014

Foretaste

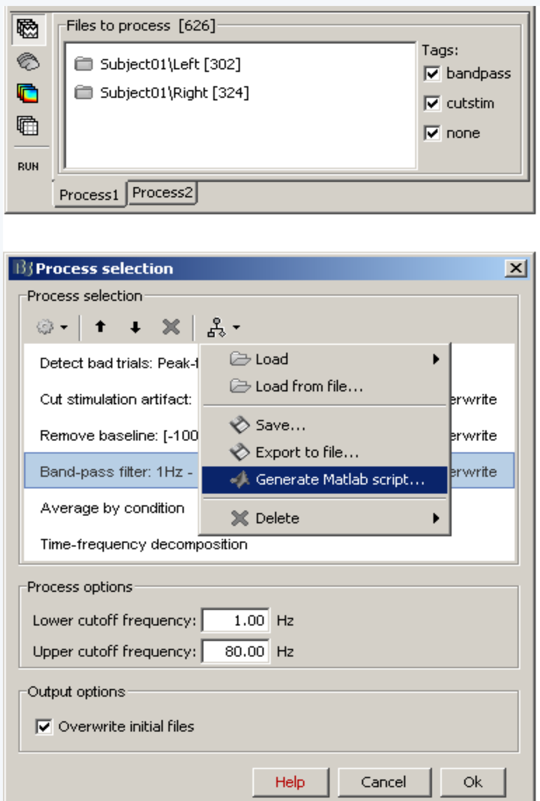
Graphic interface

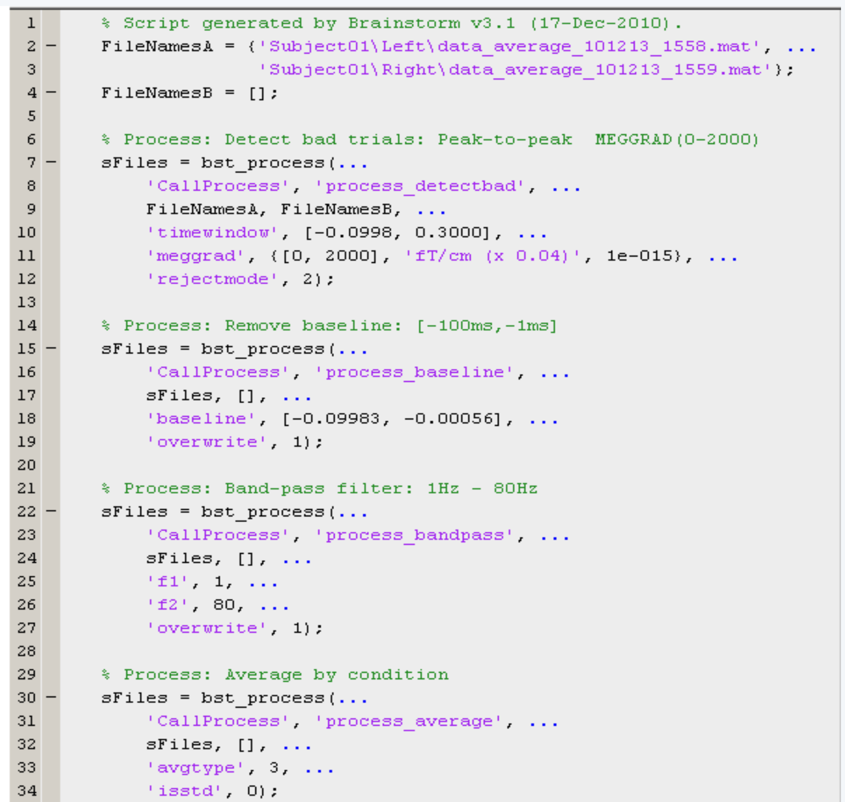


Brainstorm

Scripting environment

- Rapid selection of files and processes to apply
- Automatic generation of Matlab scripts
- Plug-in structure: easy to add custom processes





```
% Script generated by Brainstorm v3.1 (17-Dec-2010).
FileNamesA = {'Subject01\Left\data_average_101213_1558.mat', ...
              'Subject01\Right\data_average_101213_1559.mat'};
FileNamesB = [];

% Process: Detect bad trials: Peak-to-peak  MEGGRAD(0-2000)
sFiles = bst_process(...
    'CallProcess', 'process_detectbad', ...
    FileNamesA, FileNamesB, ...
    'timewindow', [-0.0998, 0.3000], ...
    'meggrad', {[0, 2000], 'fT/cm (x 0.04)', 1e-015}, ...
    'rejectmode', 2);

% Process: Remove baseline: [-100ms,-1ms]
sFiles = bst_process(...
    'CallProcess', 'process_baseline', ...
    sFiles, [], ...
    'baseline', [-0.09983, -0.00056], ...
    'overwrite', 1);

% Process: Band-pass filter: 1Hz - 80Hz
sFiles = bst_process(...
    'CallProcess', 'process_bandpass', ...
    sFiles, [], ...
    'f1', 1, ...
    'f2', 80, ...
    'overwrite', 1);

% Process: Average by condition
sFiles = bst_process(...
    'CallProcess', 'process_average', ...
    sFiles, [], ...
    'avgtype', 3, ...
    'isstd', 0);
```

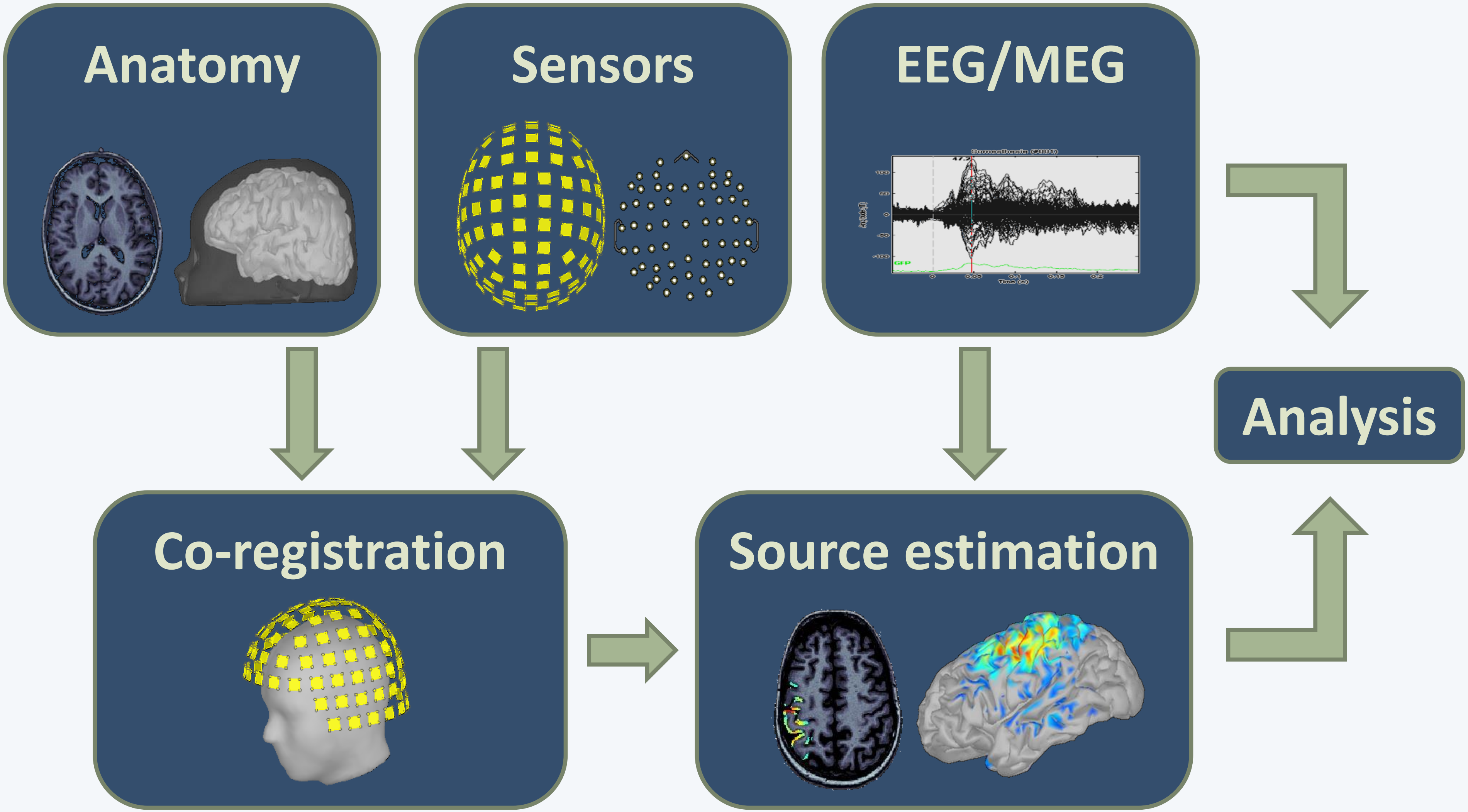
Brainstorm is…

- A free and open-source application (GPL)
- Matlab & Java: Platform-independent
- Designed for Matlab environment
- Stand-alone version also available
- Interface-based: click, drag, drop
- No Matlab experience required
- Daily updates of the software

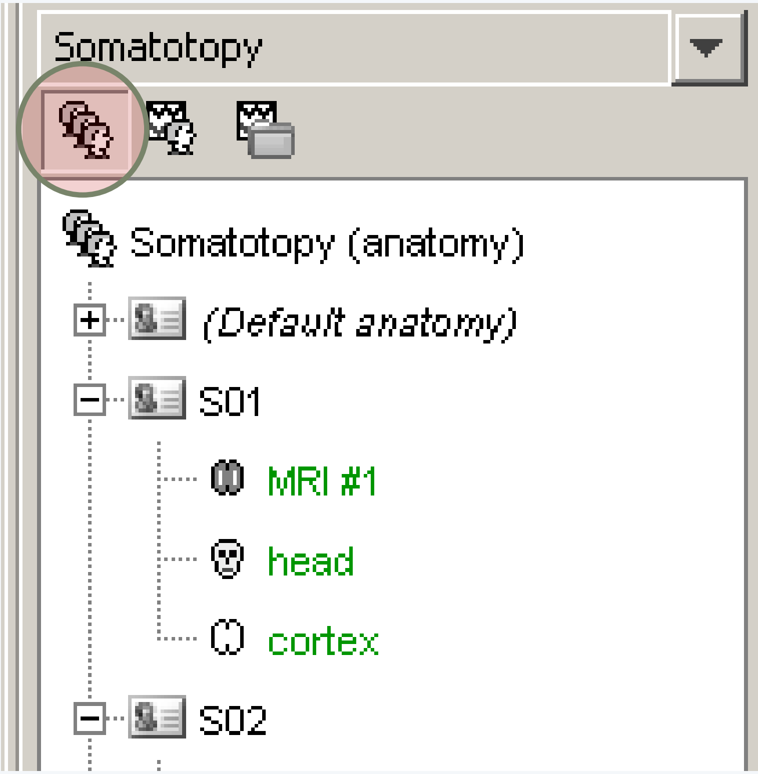
A bit of history

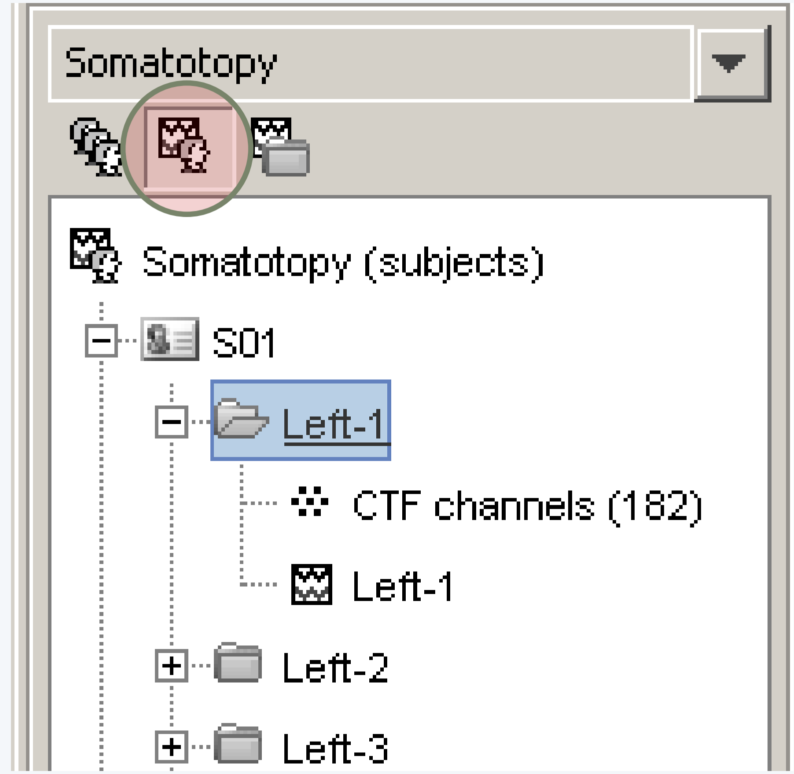
- 14 years of research and development
- Collaboration between multiple groups:
  - University of Southern California, Los Angeles, USA
  - La Salpetriere Hospital / CNRS, Paris, France
  - Neurospin / Inserm / CEA, Paris, France
  - Los Alamos National Lab, USA
  - Medical College of Wisconsin, Milwaukee, USA
  - Cleveland Clinic, USA
  - Martinos Center / MGH, USA
  - McGovern Institute / MIT, USA
  - Montreal Neurological Institute / McGill, Canada
- Over 9000 user accounts / 70 countries

Workflow


Anatomy
Sensors
EEG/MEG
Analysis
Co-registration
Source estimation

Database

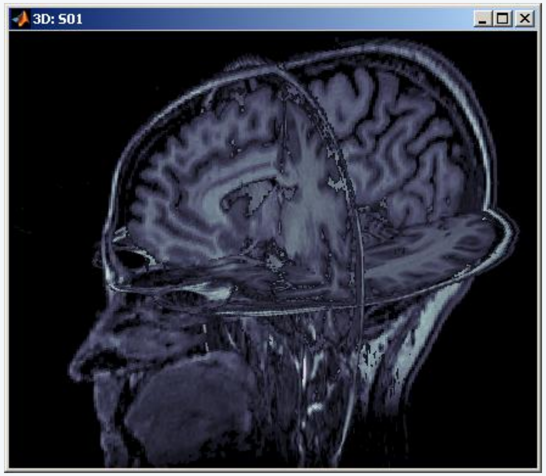




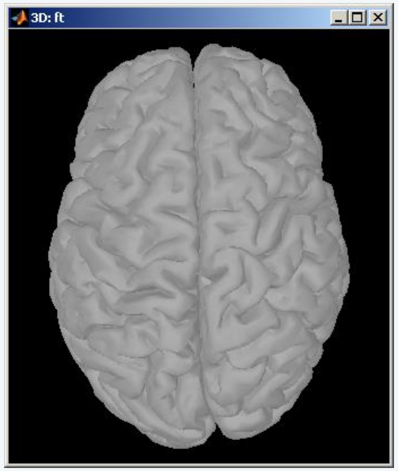
- Three levels:
  - Protocol
  - Subject
  - Condition
- Popup menus
- All files saved in Matlab .mat
- Same architecture on the disk

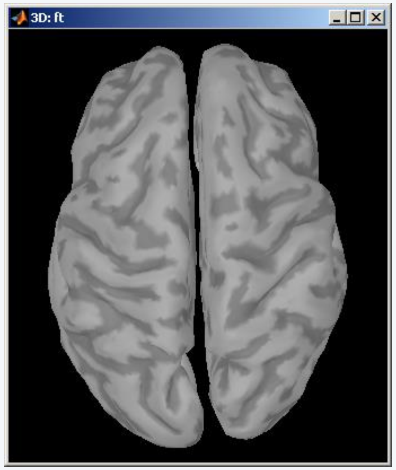
Anatomy

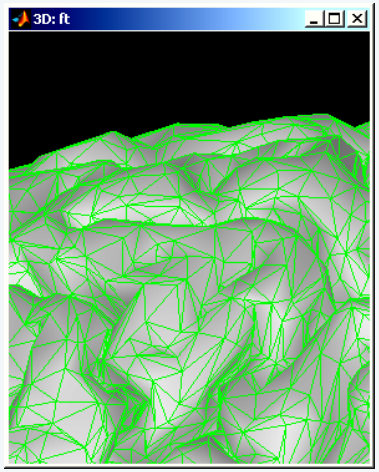
- T1-MRI volume

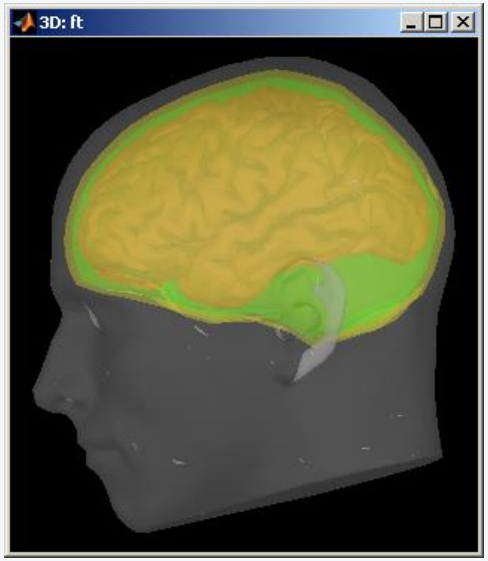


- Surfaces extracted with a dedicated software: BrainVISA, FreeSurfer, BrainSuite





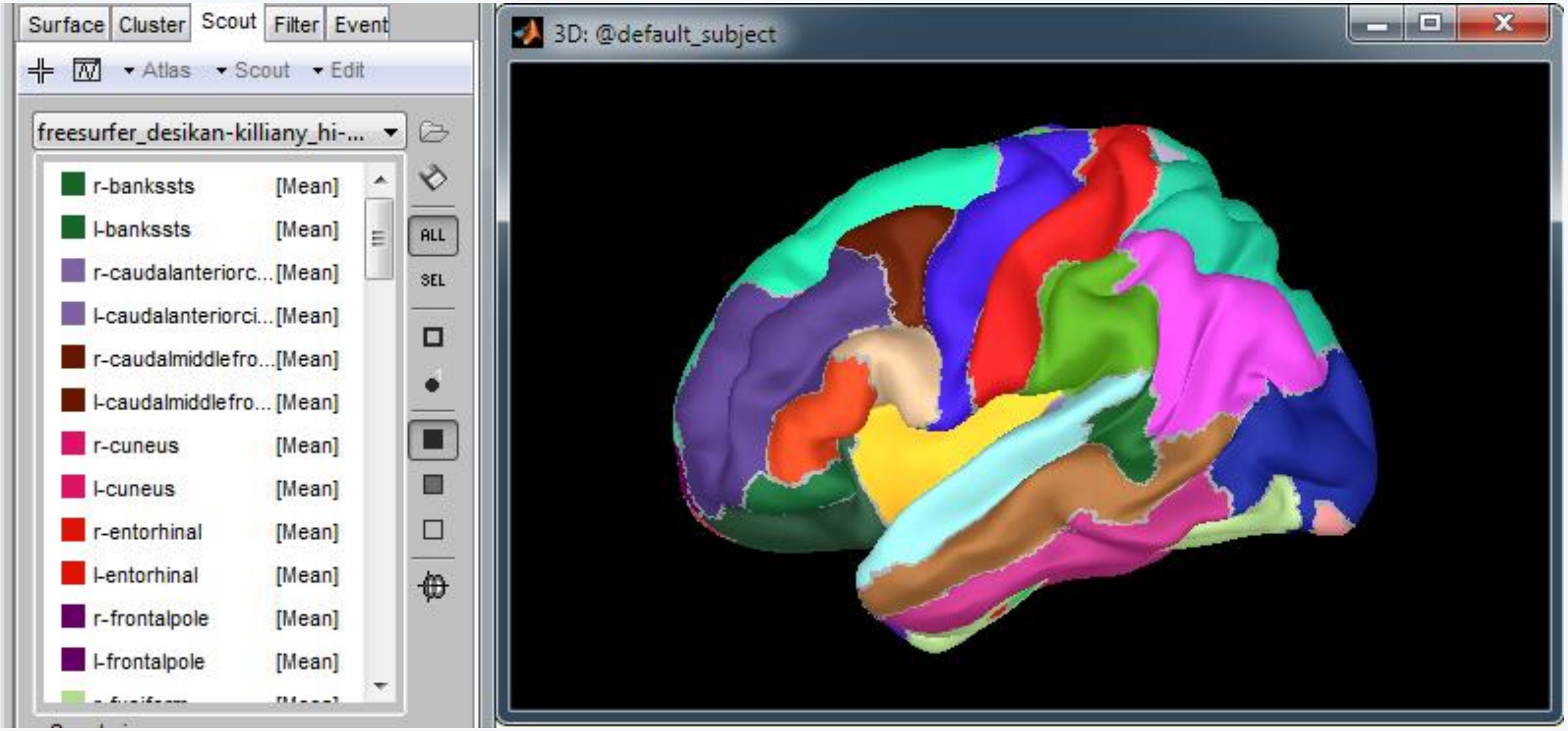




Brainstorm

Atlases

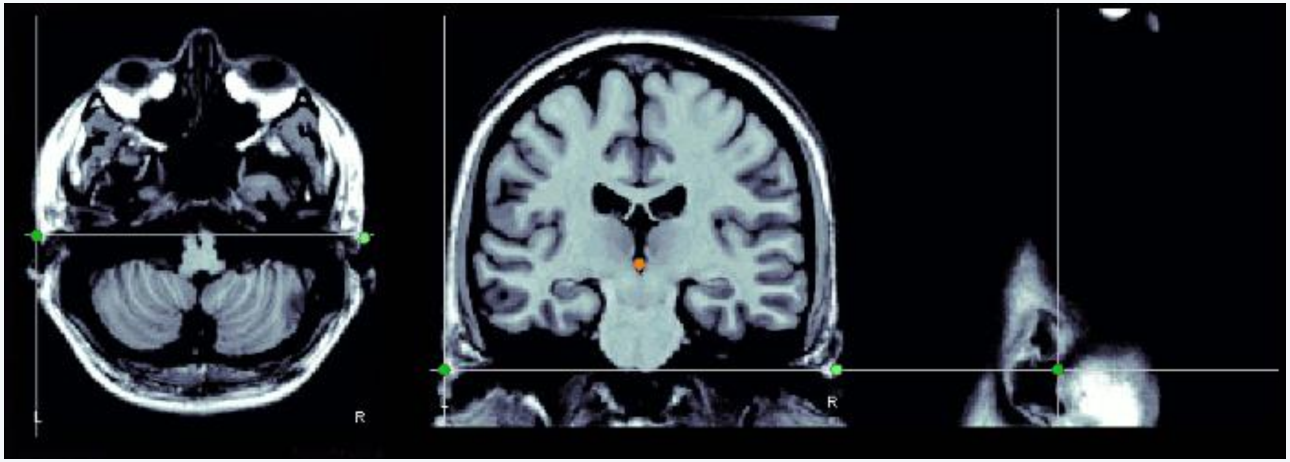
- Support for the surface-based atlases generated automatically by FreeSurfer



Brainstorm

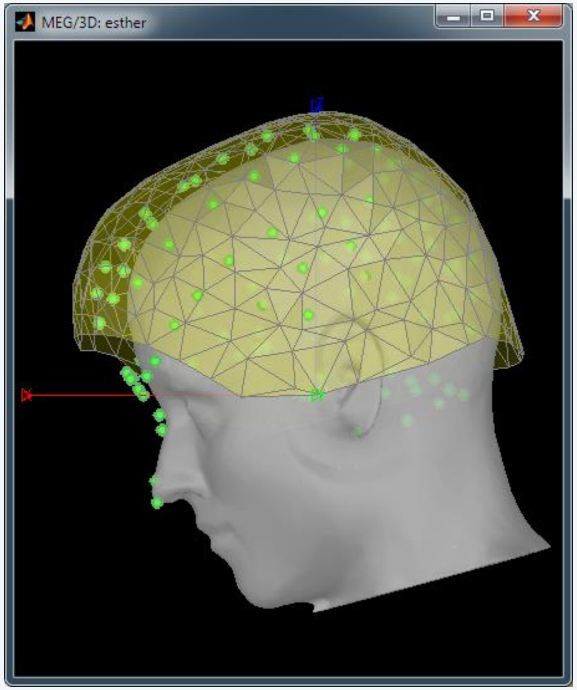
Co-registration MEG / MRI (I)

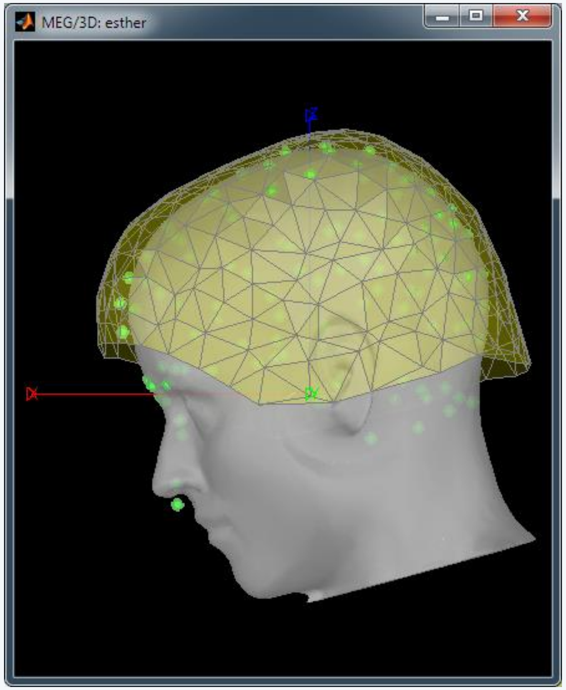
- Basic estimation based on three points (NAS,LPA,RPA)
  - MRI: Marked in the volume with the MRI Viewer
  - MEG: Obtained with a tracking system (Polhemus)



Co-registration MEG / MRI (2)

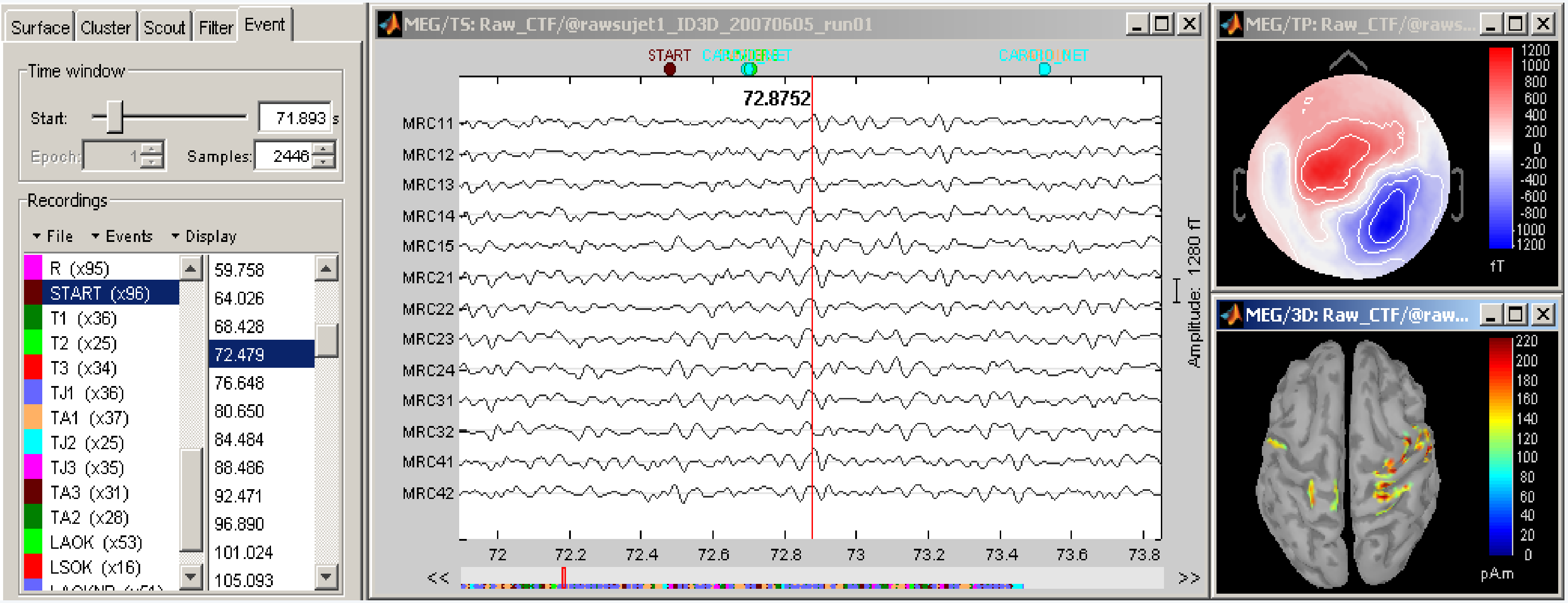
- Automatic adjustment based on head shape
  - Trying to fit the head points (Polhemus) with the head surface (from the MRI)
- Final registration must be checked manually





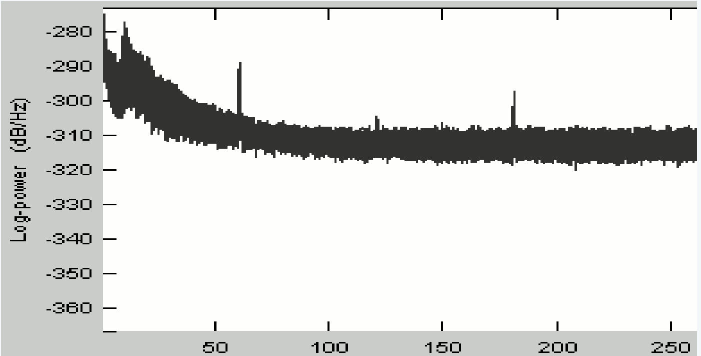
Continuous recordings

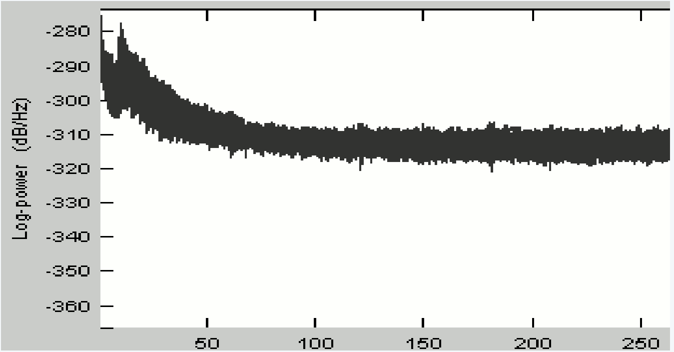
- Manual inspection of the recordings
- Identify the noise sources
- Mark bad channels and bad segments
- Check stimulus markers, add custom events



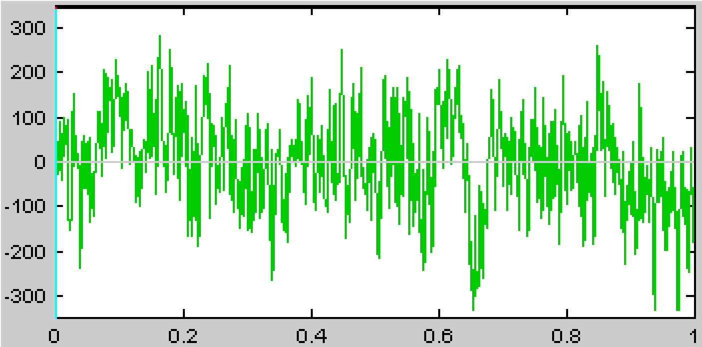
Brainstorm

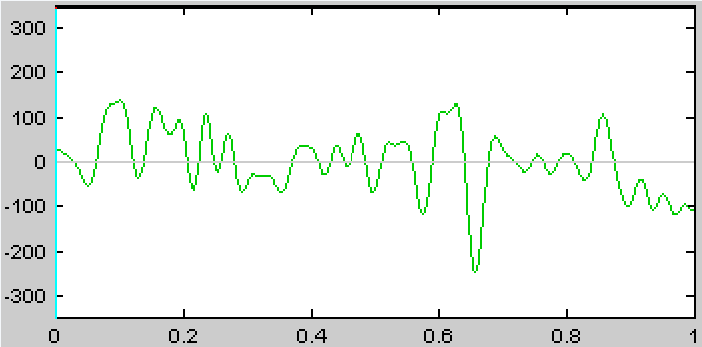
- Sinusoid removal:
  Remove 50Hz or 60Hz power line contamination



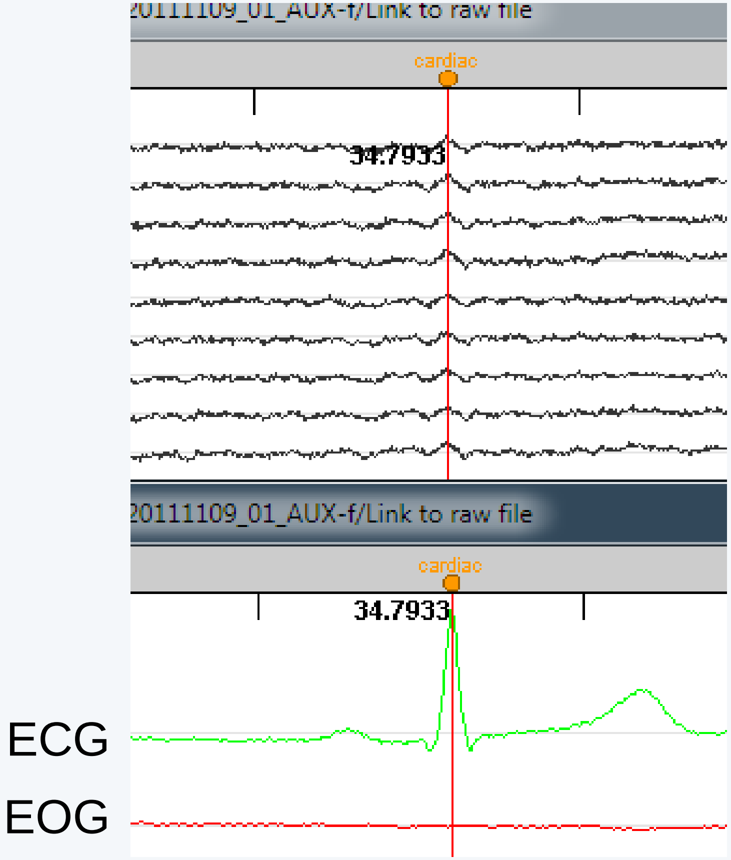


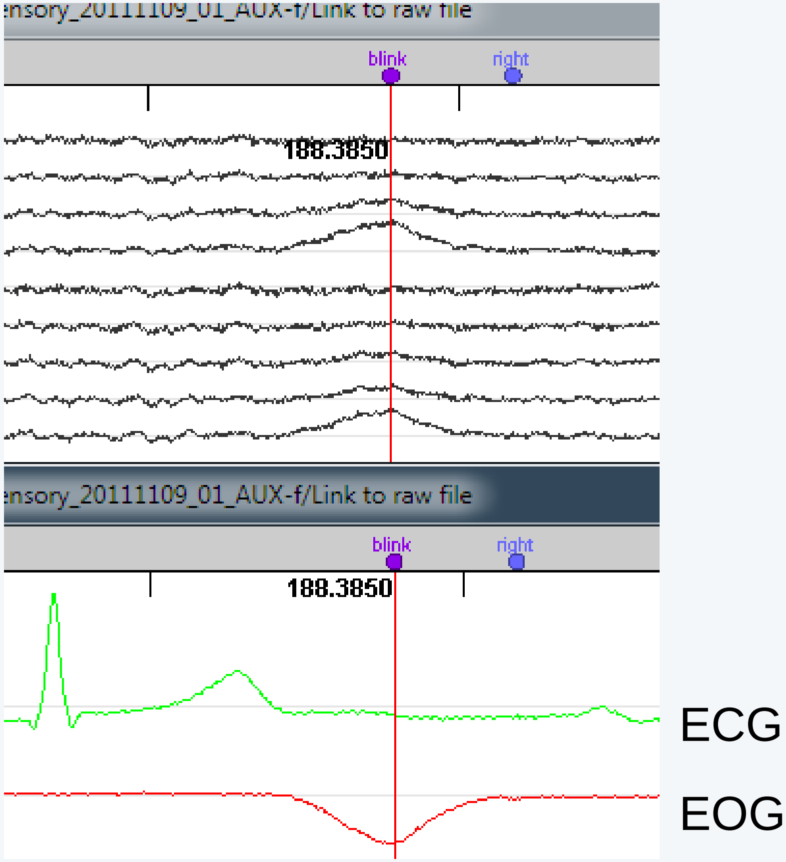
- Band-pass filter:
  Remove slow drifts and high frequencies





- Artifact detection and removal:
  - heartbeats, eye blinks, movements, …

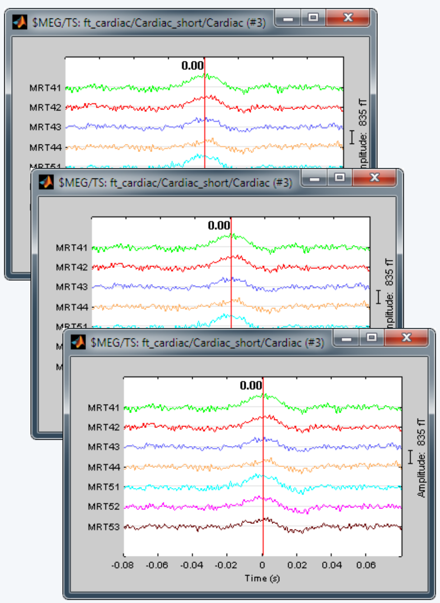




- Two categories of artifacts:
  - Well defined, reproducible, short, frequent:
    - Heartbeats, eye blinks, some stimulators
    - Unavoidable and frequent: we cannot just ignore them
    - Can be modeled and removed from the signal efficiently
  - All the other events that can alter the recordings:
    - Movements, building vibrations, metro nearby…
    - Too complex or not repeated enough to be modeled
    - Safer to mark them as bad segments, and ignore them

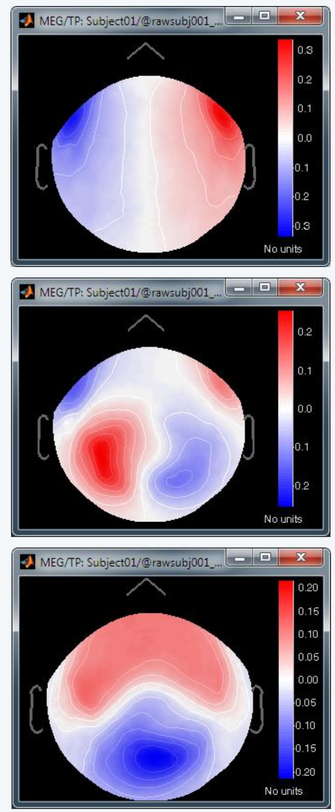
Signal-Space Projection (SSP)

- Detect artifacts
- Concatenate epochs



PCA

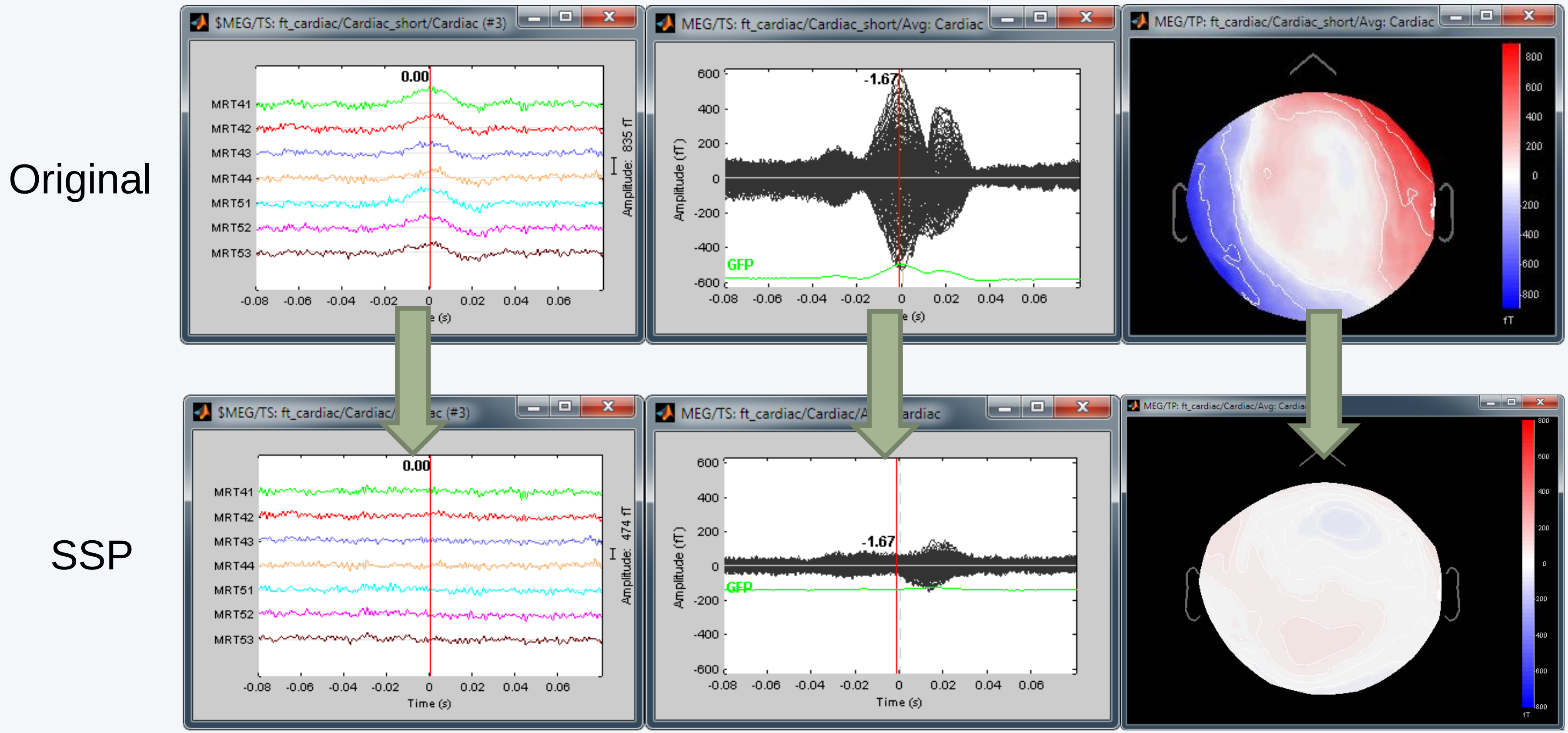
Spatial components



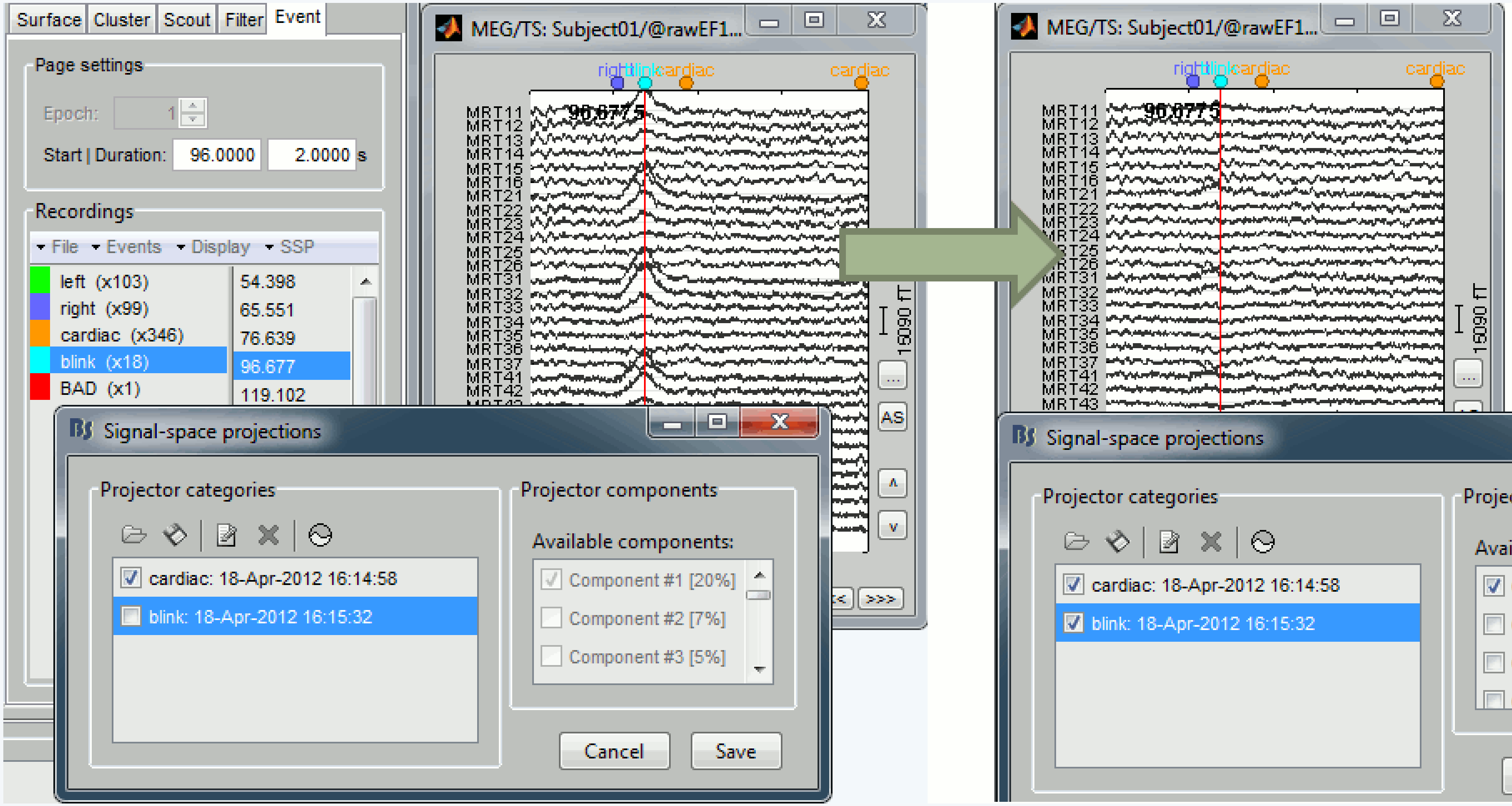
- Select components
- Compute projectors (linear operator)
- Apply to EEG/MEG

Brainstorm

- Example: Cardiac artifact

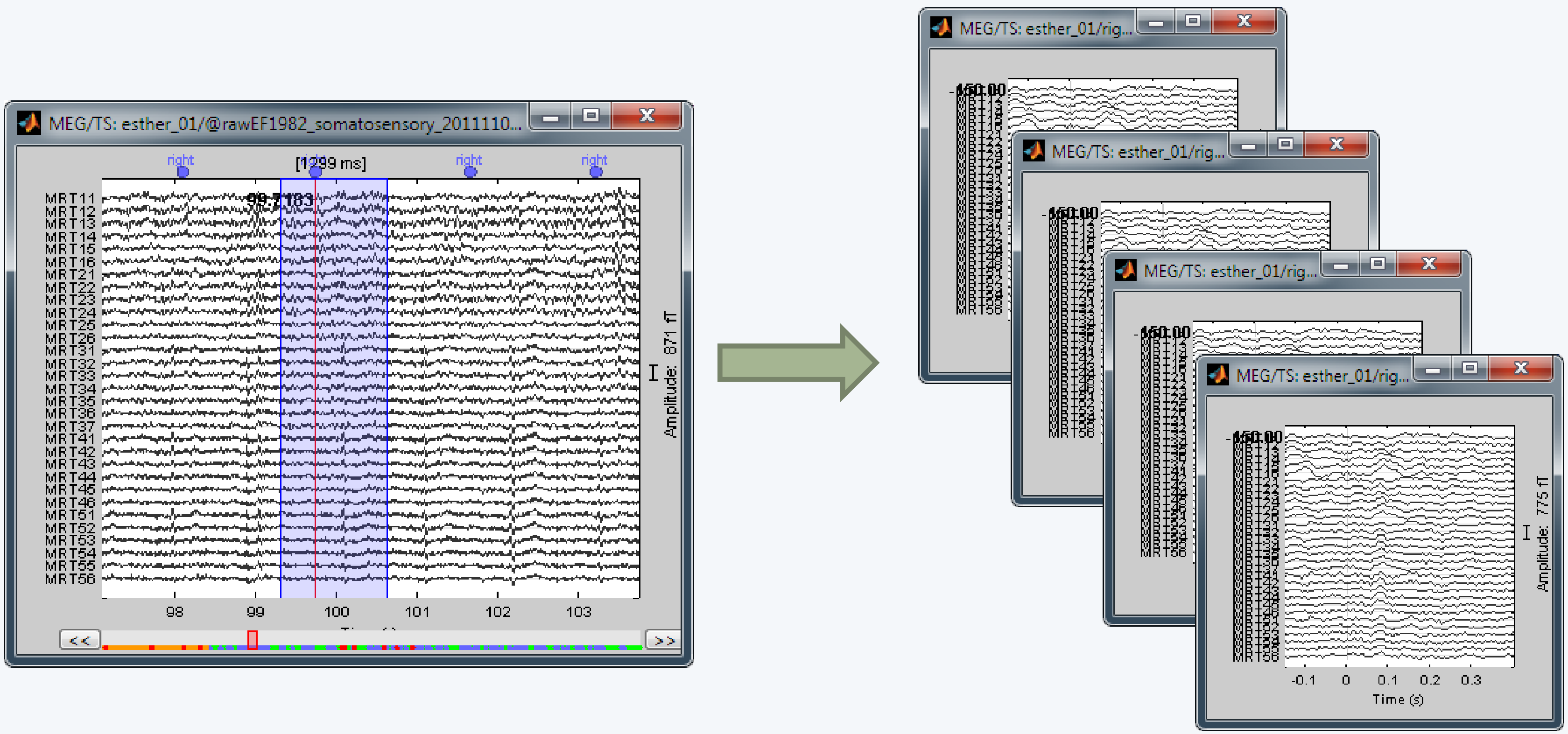


Brainstorm



Surface Cluster Scout Filter Event
Page settings
Epoch: 1
Start | Duration: 96.0000 2.0000 s
Recordings
File Events Display SSP
left (x103) 54.398
right (x99) 65.551
cardiac (x346) 76.639
blink (x18) 96.677
BAD (x1) 119.102
MEG/TS: Subject01/@rawEF1...
right blink cardiac cardiac
96.6775
16090 fT
Signal-space projections
Projector categories
cardiac: 18-Apr-2012 16:14:58
blink: 18-Apr-2012 16:15:32
Projector components
Available components:
Component #1 [20%]
Component #2 [7%]
Component #3 [5%]
Cancel
Save

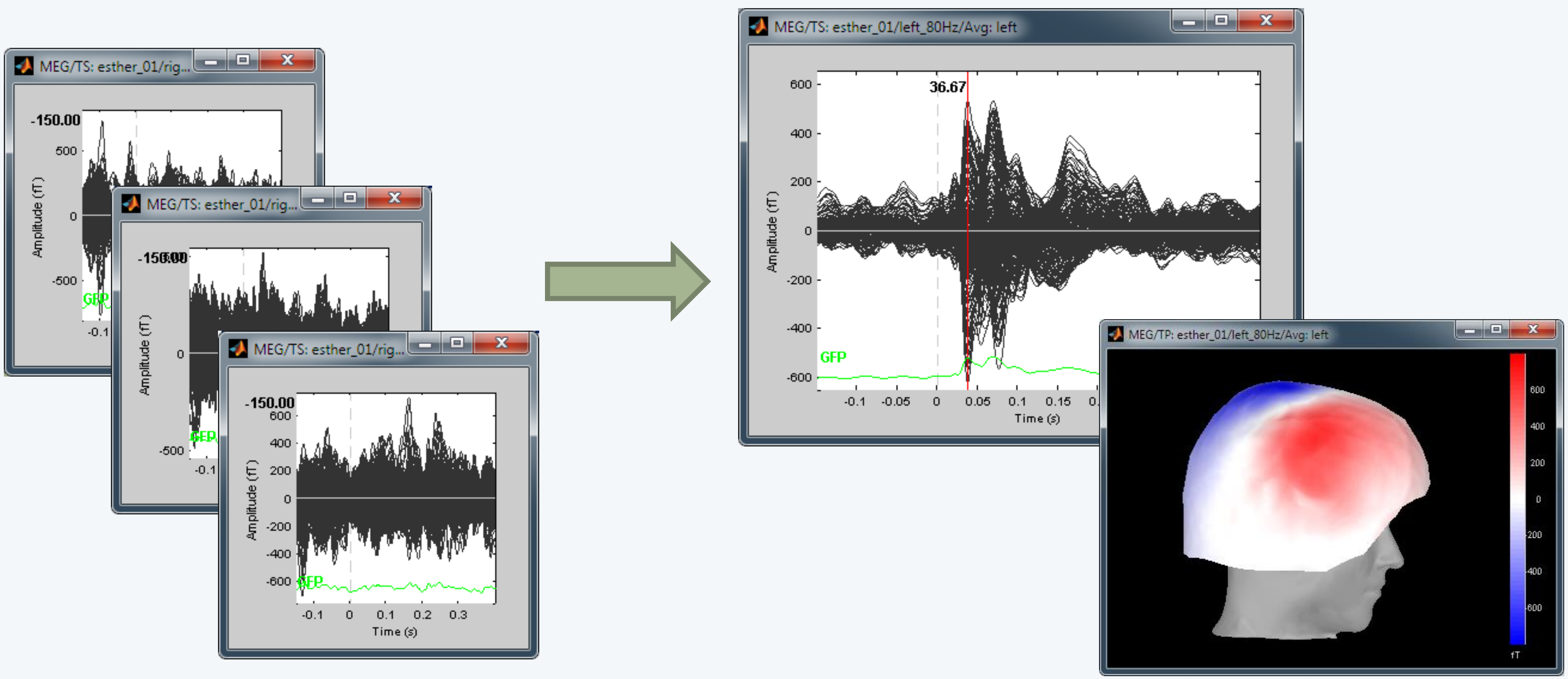
- Epoching: extraction of small blocks of recordings around an event of interest (stimulus, spike…)



Brainstorm

- Averaging all the trials: Reveals the features of the signals that are locked in time to a given event

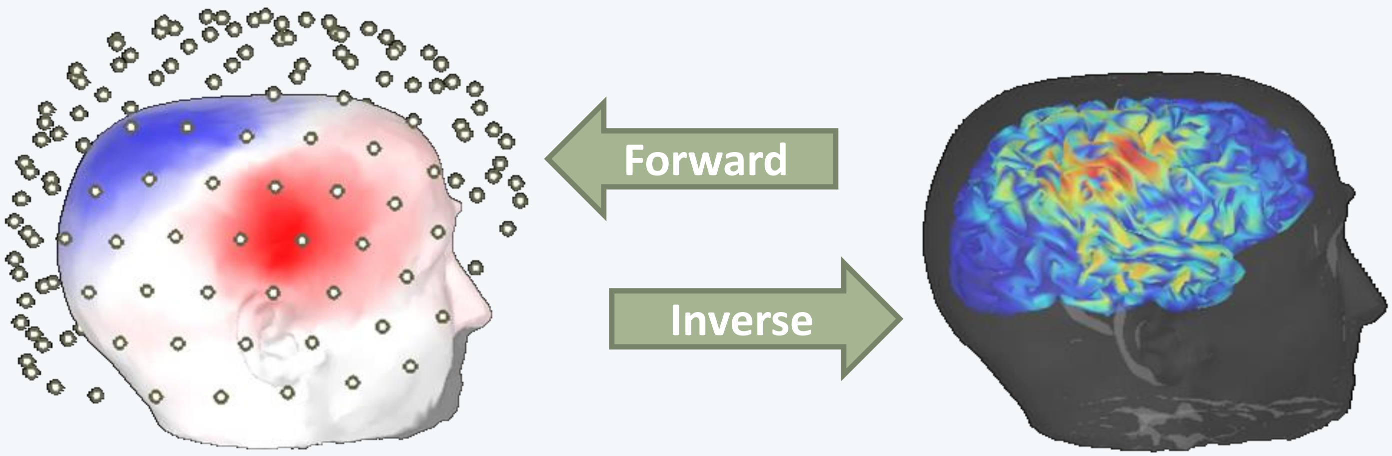
  => Evoked-response field (or potential)



Brainstorm

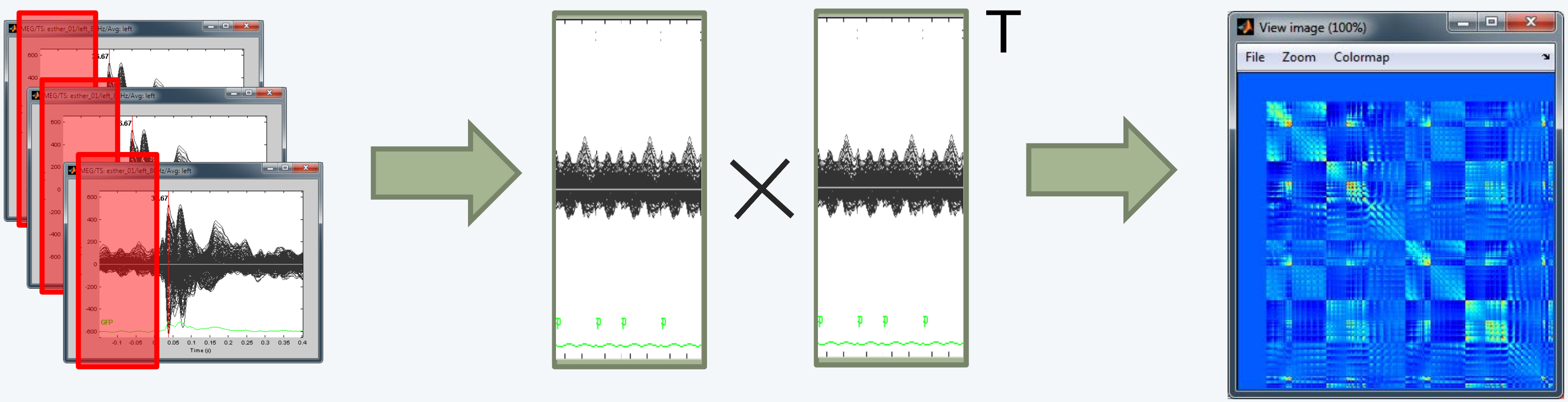
Source estimation

- Source space: cortex surface (or full head volume)
- Forward model = head model
  Sources => Sensors
- Inverse model: Minimum norm estimates
  Sensors => Sources

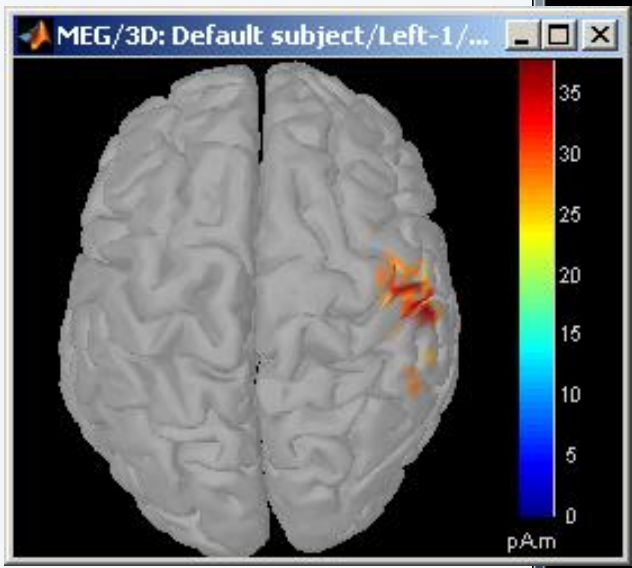


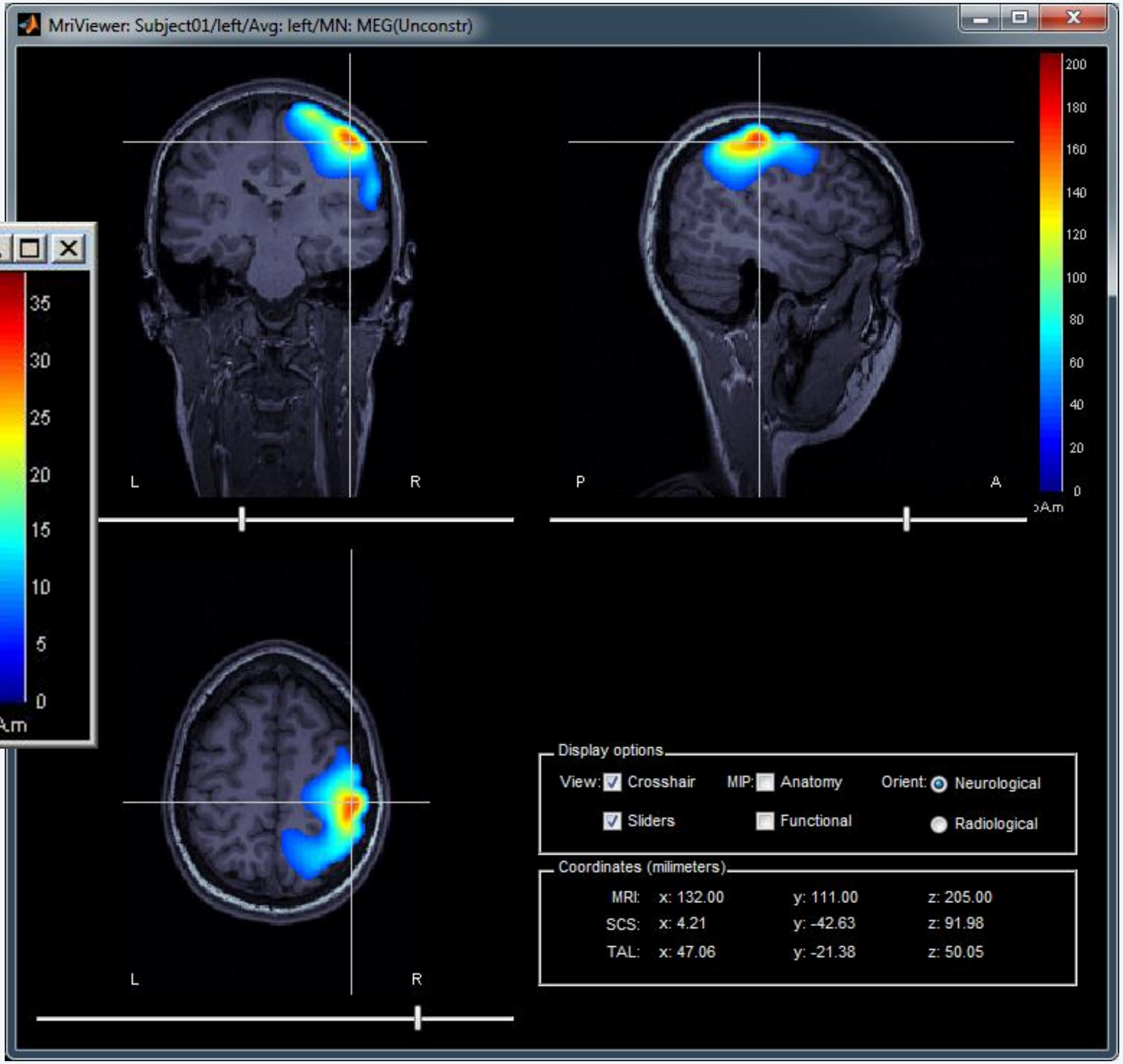
Noise covariance matrix

- Inverse model (minimum norm estimates) requires an estimation of the level of noise on the sensors
- Noise covariance matrix = covariance of the segments that do not contain any “meaningful” data
- Typically: empty room measures, or pre-stim baseline



Source activity

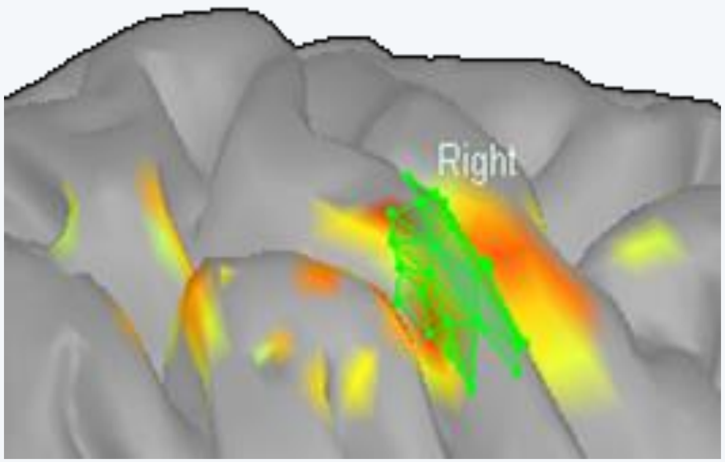


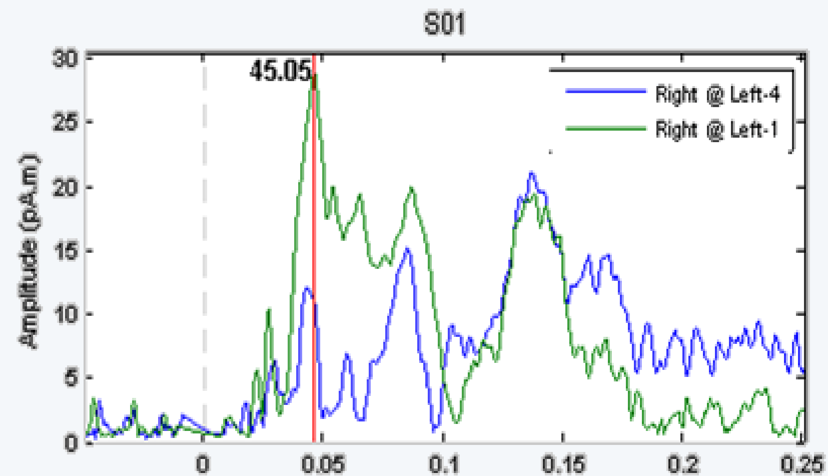


Brainstorm

Regions of interest

- Regions of interest at cortical level (scouts)
  = Subset of a few dipoles in the brain
  = Group of vertices of the cortex surface





Source estimation: MEG

- Recommended in MEG analysis:
  - The subject head can move in the helmet
  - One sensor is not corresponding to one brain region
  - Different types of sensors (magneto / gradiometers)
  - Difficult to read, reproduce or compare

- Converting to source space helps solving those issues

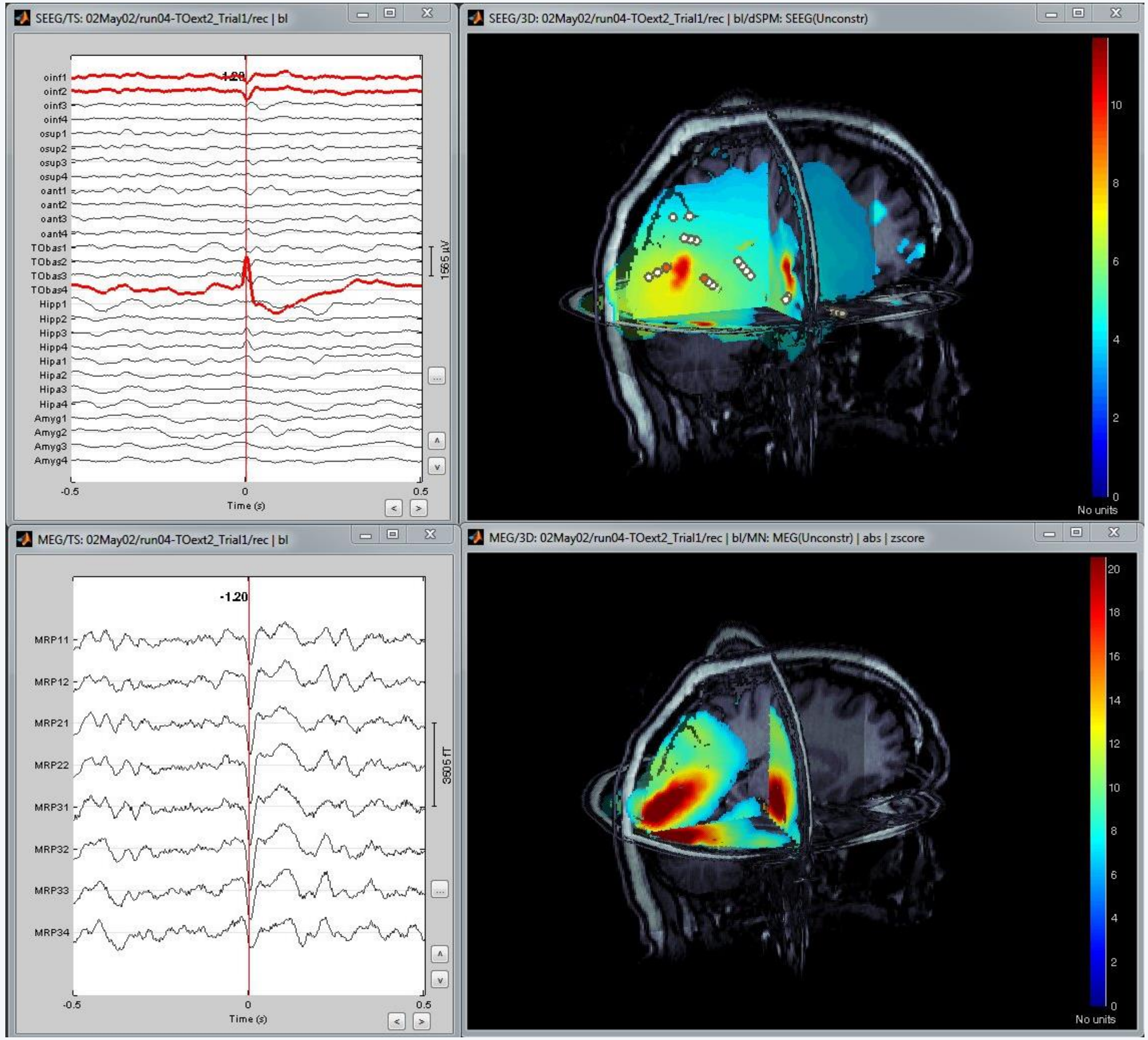
Multi-modal imaging

Easy integration of:

- MEG
- EEG
- ECoG
- SEEG

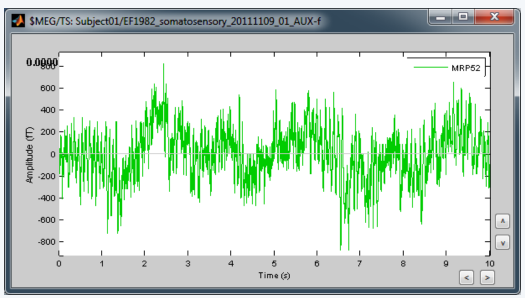
In a near future:

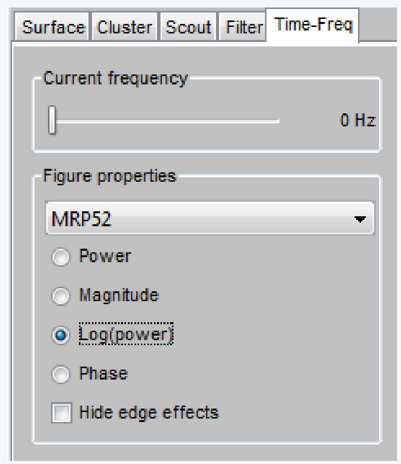
- NIRS

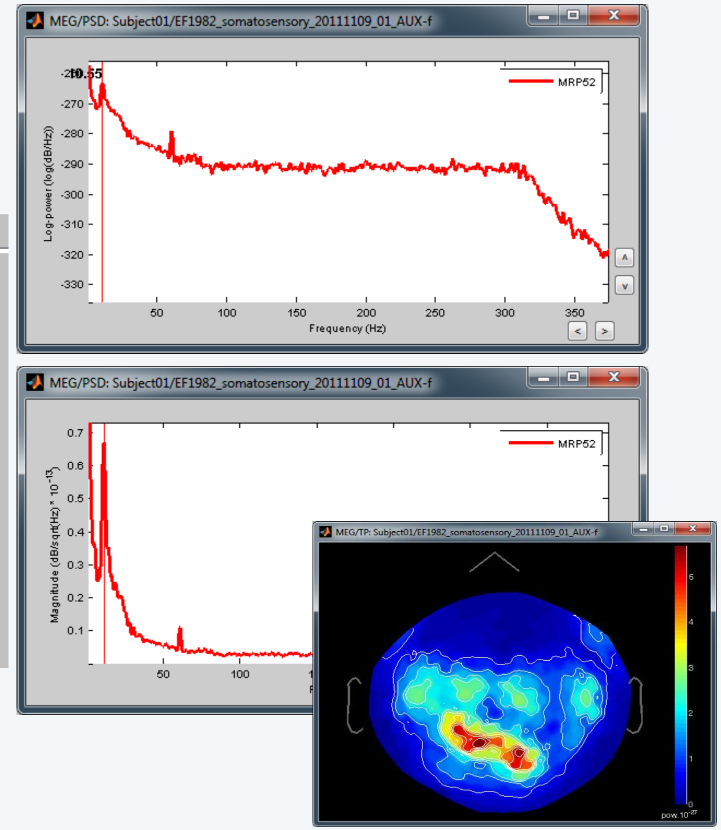


Spectral analysis

- Fast Fourier transform (FFT)
- Power spectrum density (PSD)



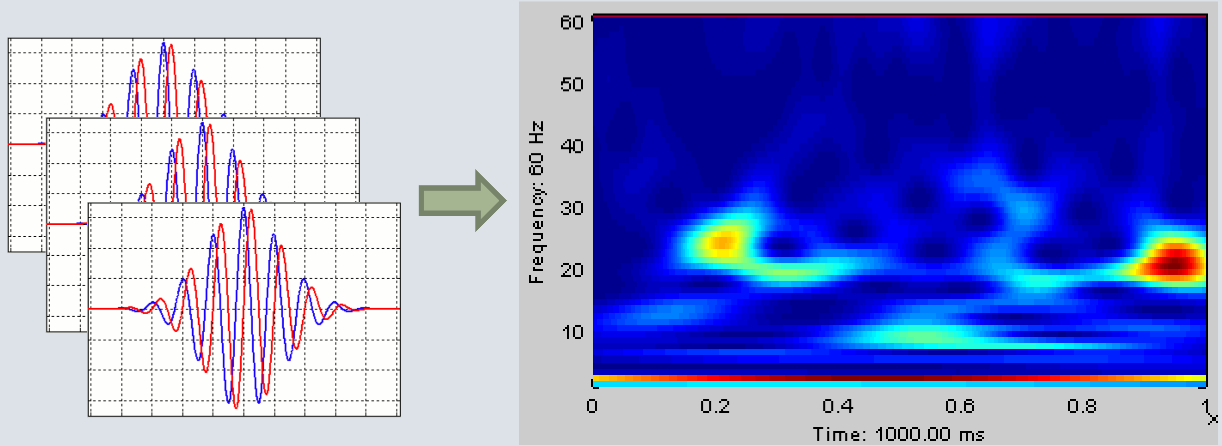


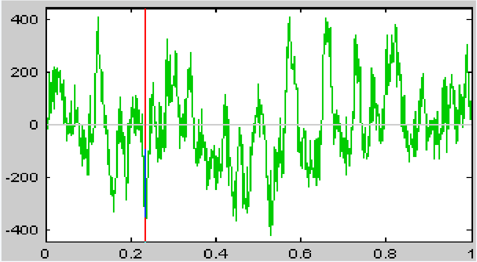


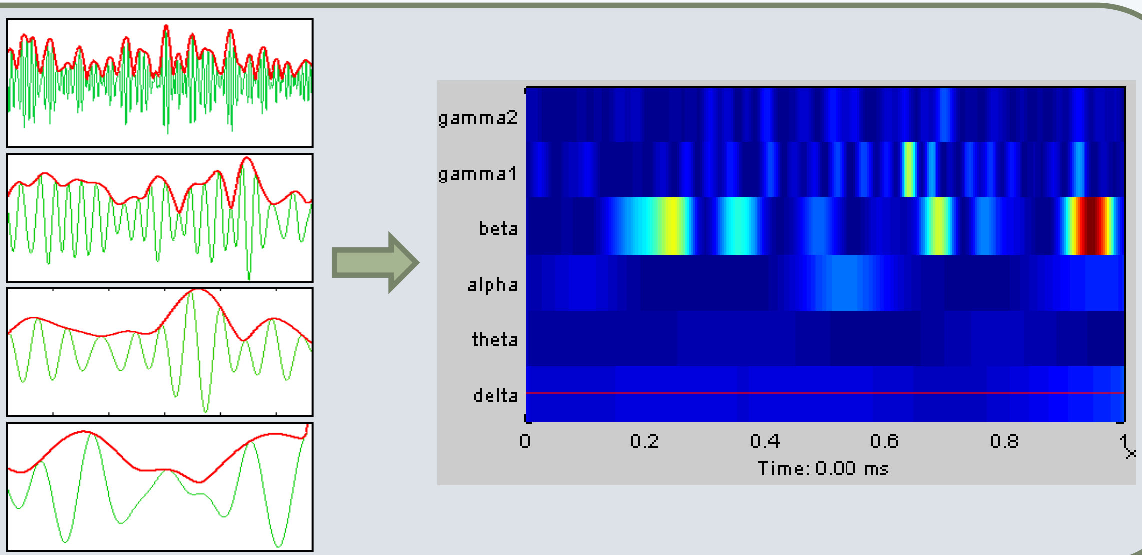
Brainstorm

Time-frequency

Morlet wavelets



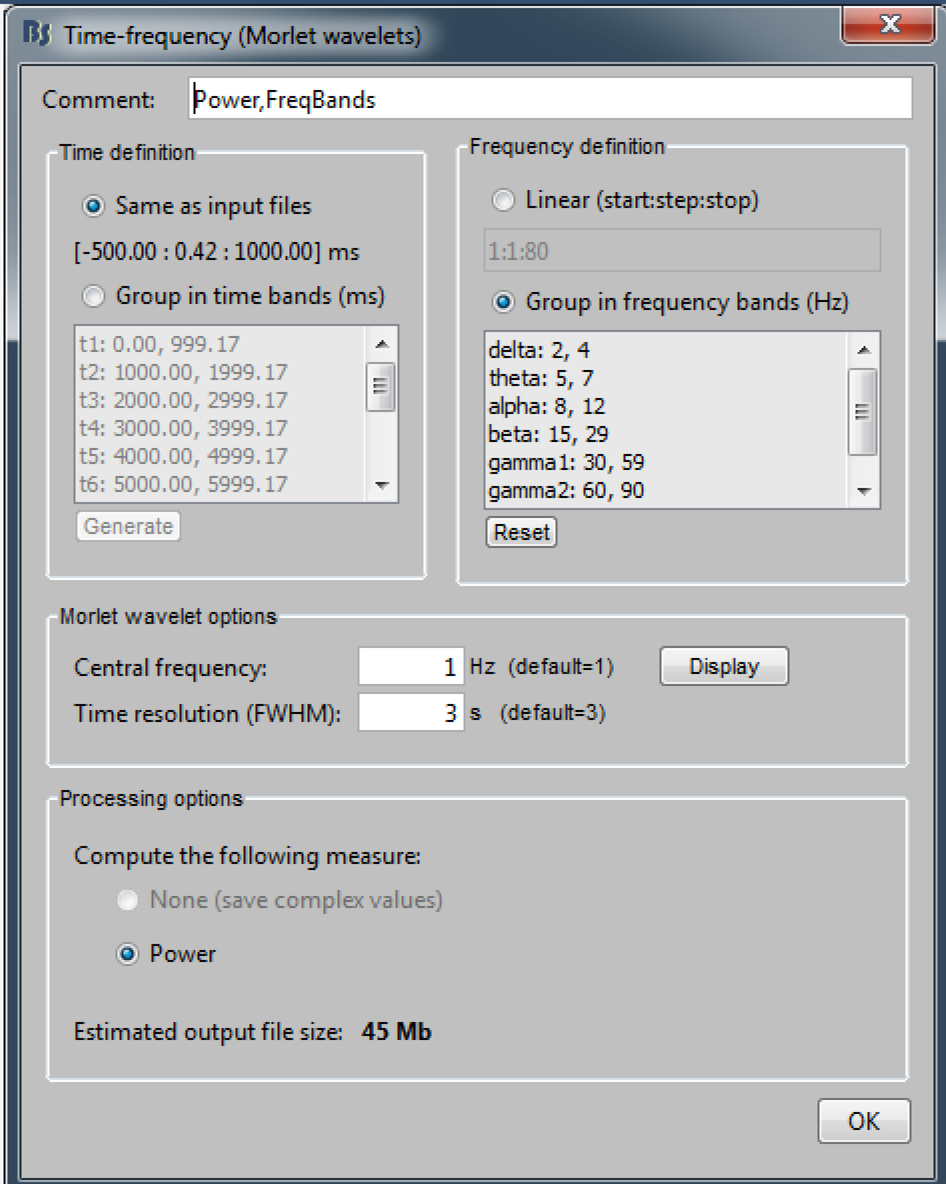


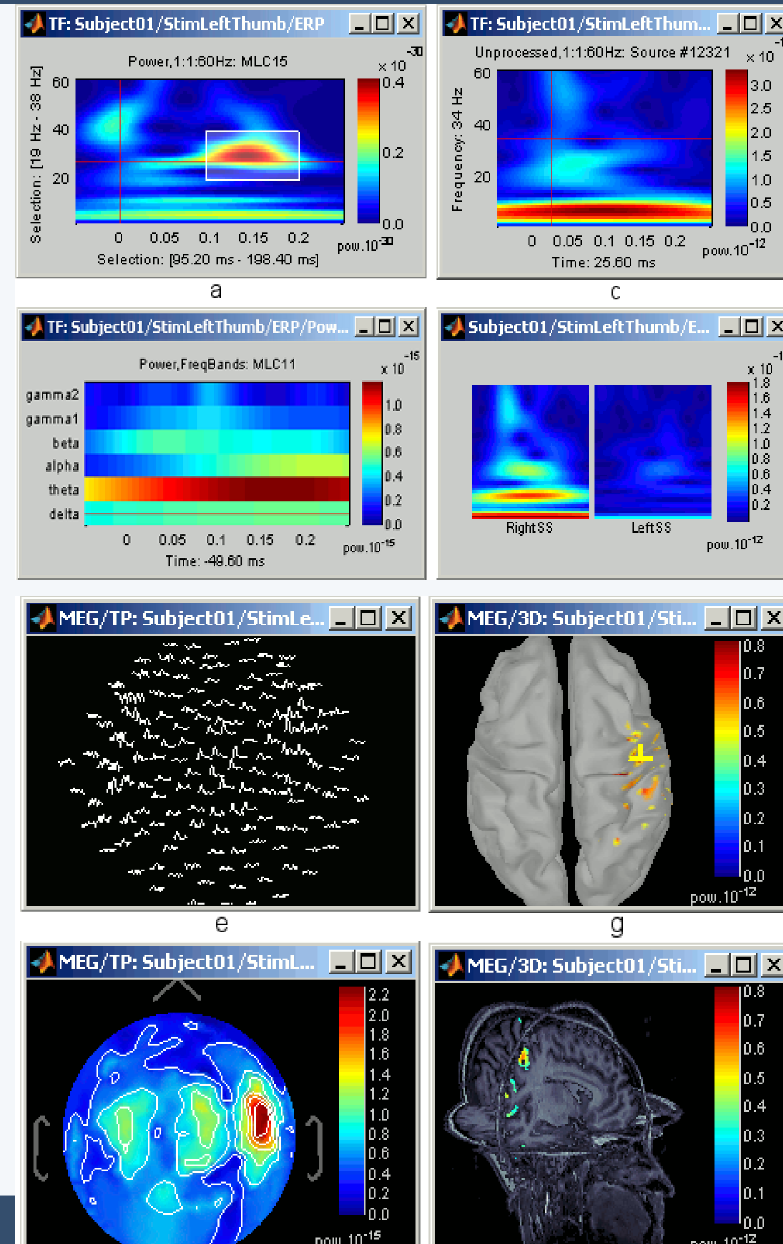


Hilbert transform

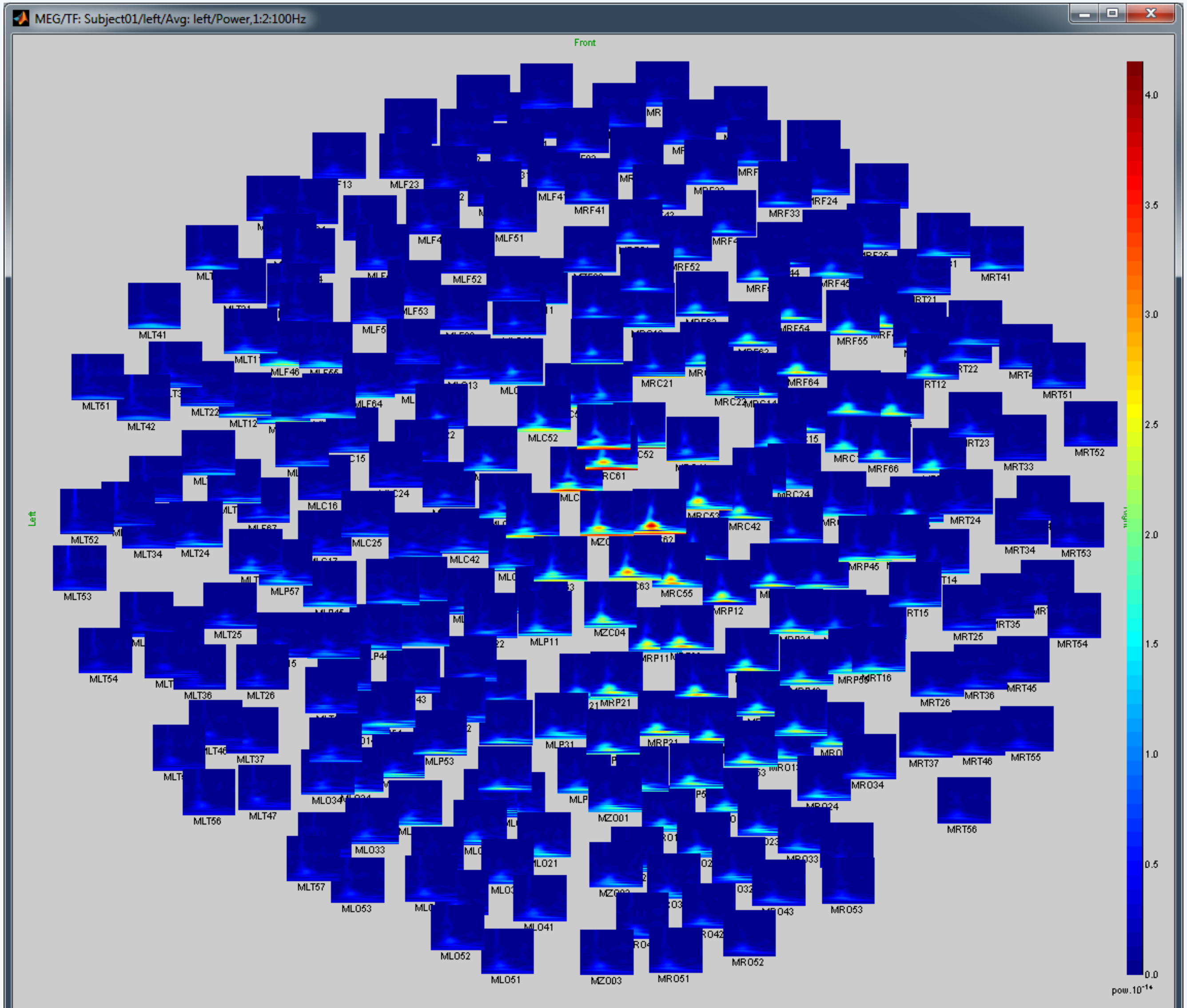
+ band-pass filter

Time-frequency





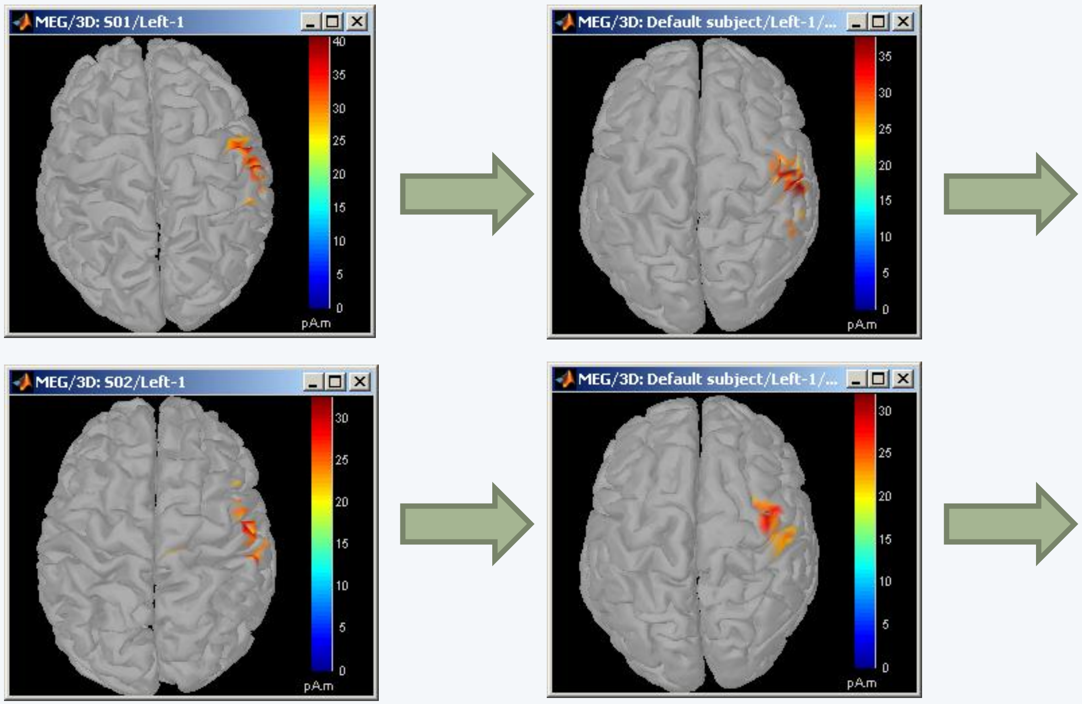
Time-frequency



- Registration of individual brains on a template

Subject 1

Subject 2



Individual anatomy

Standard anatomy

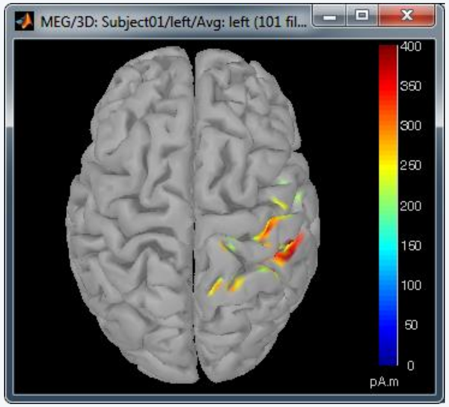
Group analysis

Average
Contrast
...

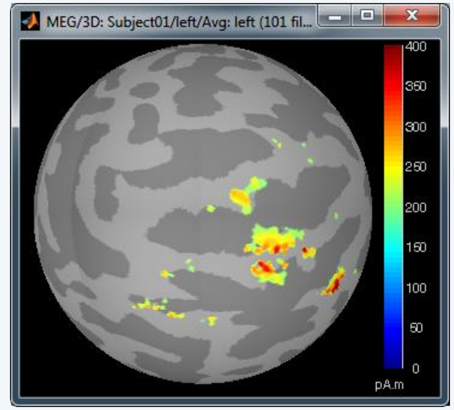
Brainstorm

Group analysis

Subject



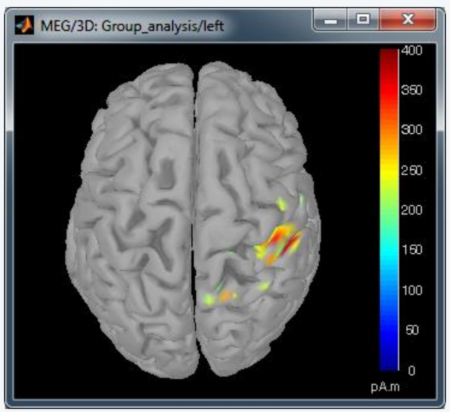
FreeSurfer registration



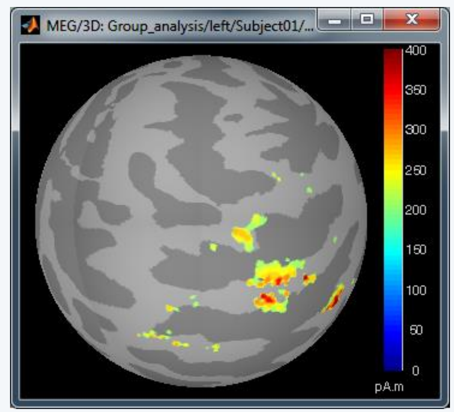
Subject anatomy
Right hemisphere

Shepard interpolation

Default anatomy



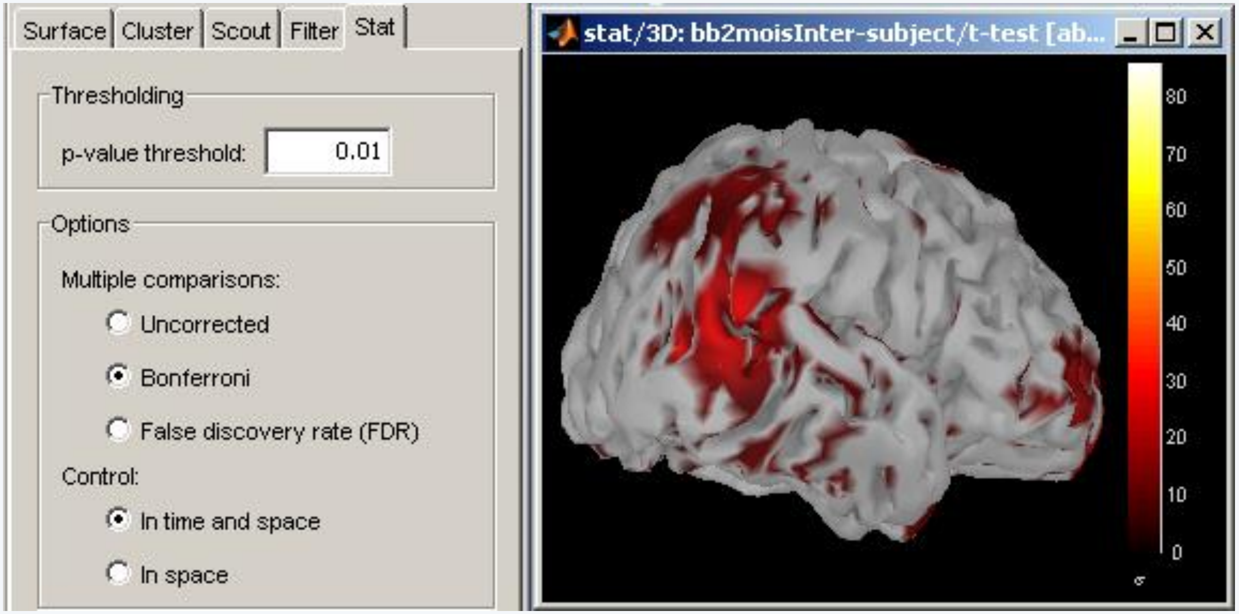
FreeSurfer registration



Template
Right hemisphere

- Contrasts between subjects or conditions
- Statistical analysis: z-score, t-test
- Quick extraction of measures from complex paradigms

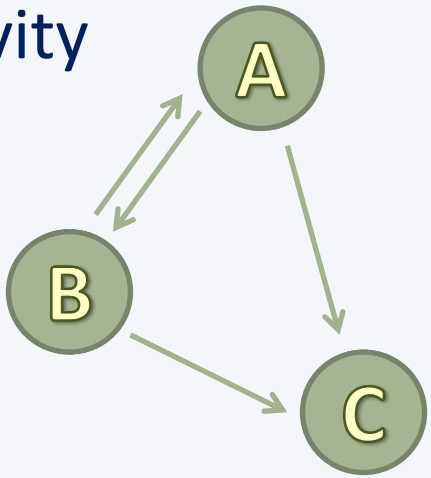
=> Export to: SPM, R, Excel, Statistica, SPSS, Matlab…



Connectivity

- Objectives: Describe the interaction between two brain regions, identify the brain networks

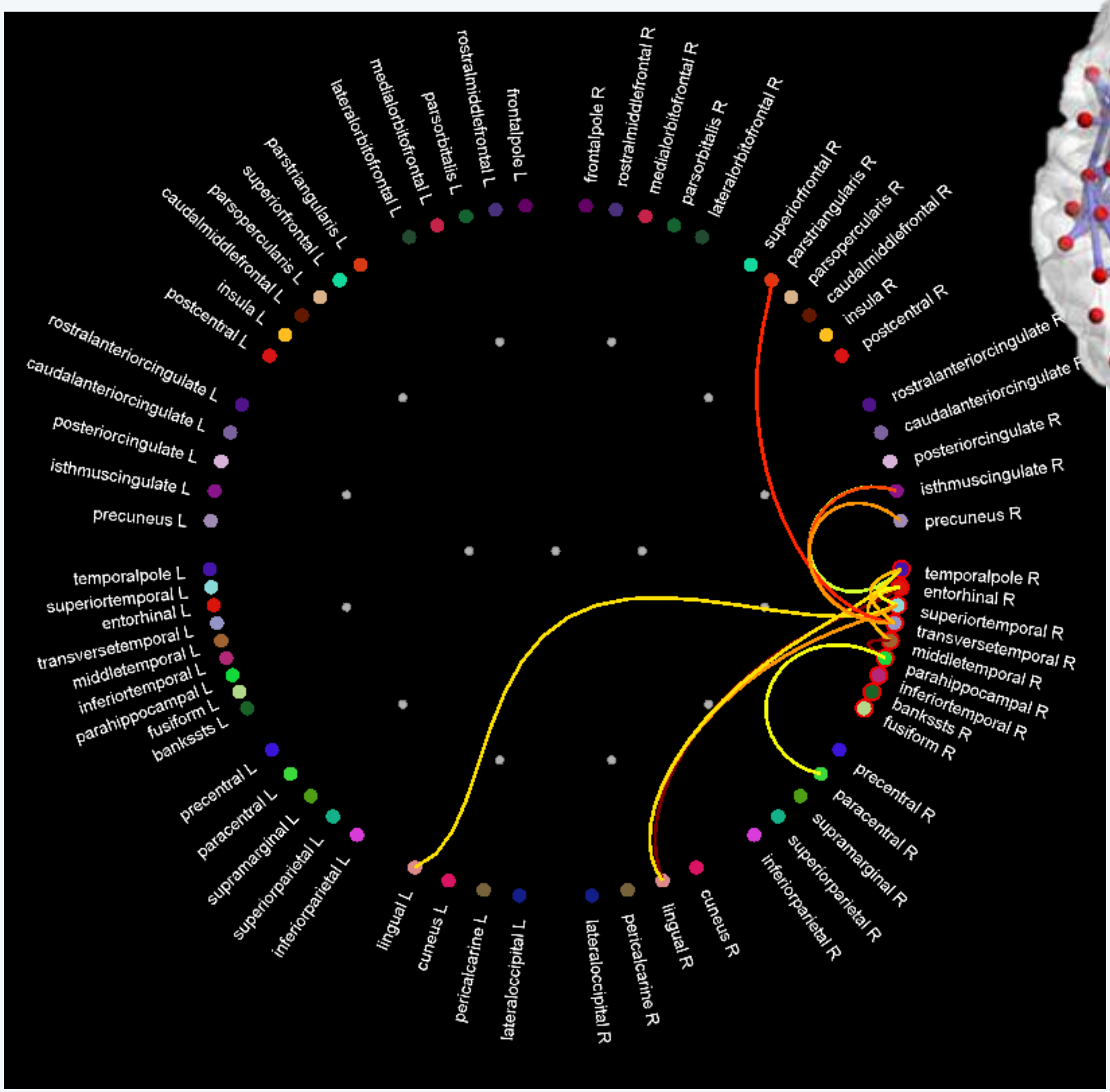
- Non-directed: Functional connectivity
  - Correlation / Coherence
  - Phase locking value

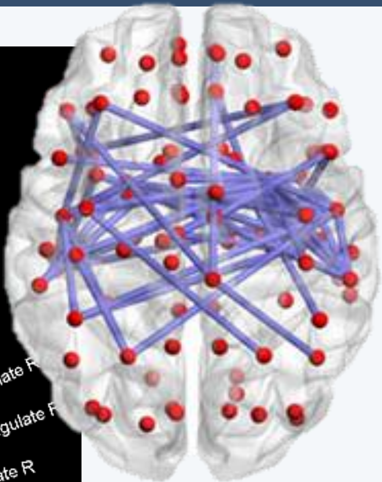


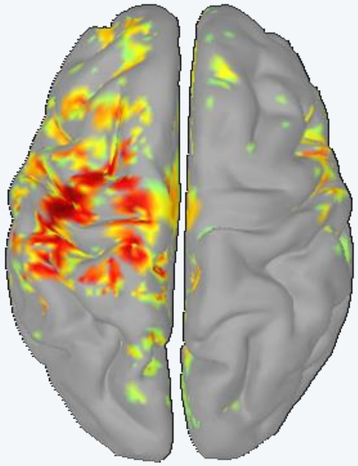
- Directed: Effective connectivity
  - Granger causality

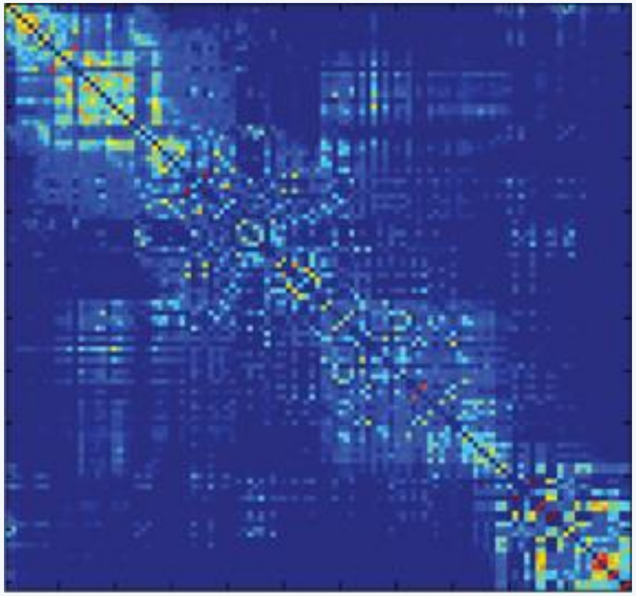
- Both at sensor and source levels

Connectivity





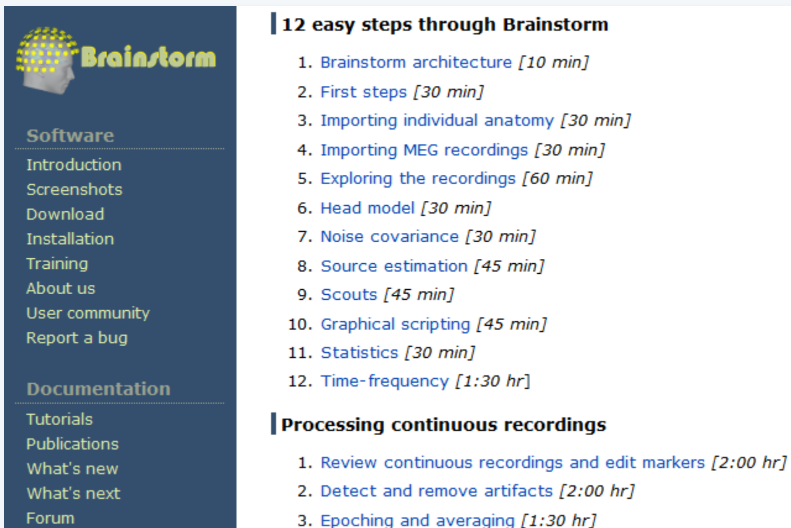


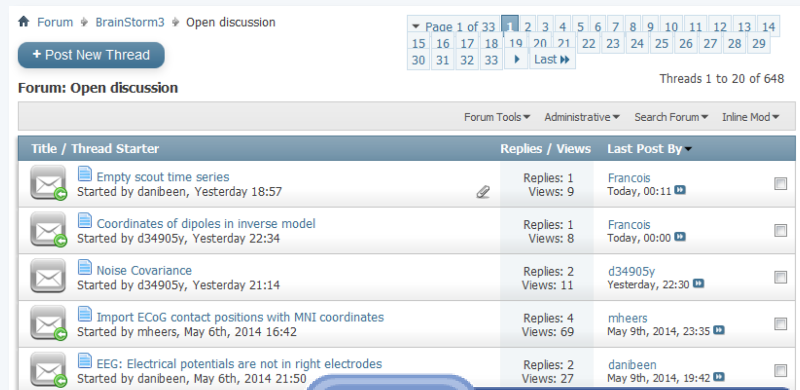


Brainstorm

User support

- Online tutorials: 20-hour self-teaching program
- Active user forum: 150 posts/month
- Daily updates: 500 downloads/month





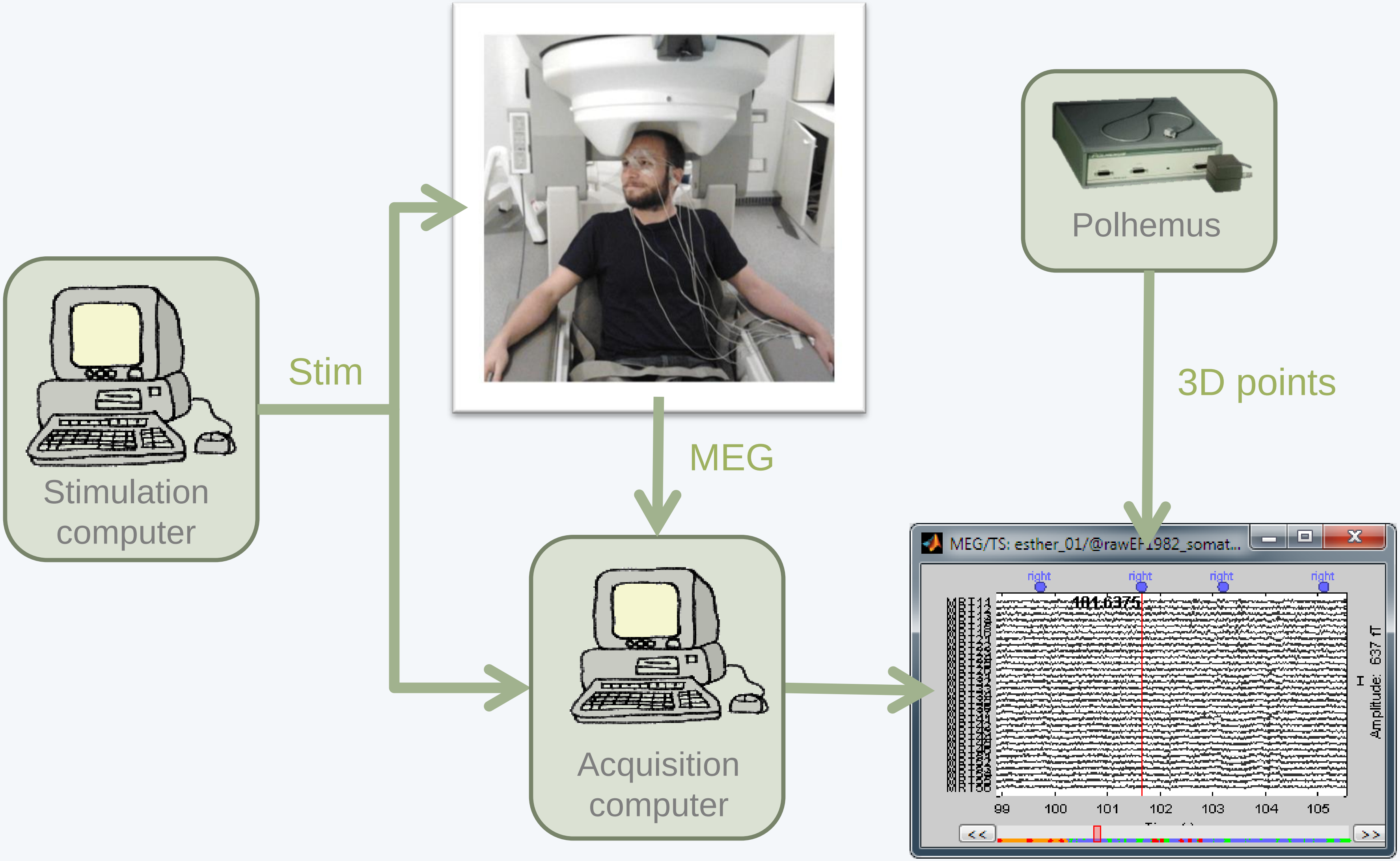
Find us on facebook

- Contact us for specific questions and requests:
  We will help you adding the features you need

- Median nerve stimulation
  (Nov 2011, Montreal Neurological Institute, McGill)

  – Random electric stimulation of both arms
  – ~ 100 trials per arm
  – Acquisition at 1200 Hz
  – Recorded on CTF 275 MEG sensors
    + 26 reference sensors
    + EOG + ECG + STIM + … = 302 channels
  – 6 minutes of recordings, 500 Mb

Acquisition setup



To-do list

- Creation of a new protocol, with one subject
- Preparation of the anatomy (MRI, surfaces)
- Anatomical atlases
- Co-registration MRI / MEG
- Reviewing the continuous file
- Correcting for eye blinks with SSP
- Epoching and averaging
- Source estimation

To-do list

- Regions of interest (scouts)
- Frequency analysis: FFT, time-frequency, Hilbert
- Functional connectivity

- Scripting interface
- Group analysis and statistics
- Registration on default anatomy

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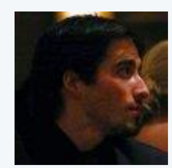

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