

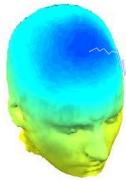
# Evaluating ICs



- 1. ICA introduction**
- 2. Run ICA**
- 3. IC evaluation**
- 4. Identify IC artifacts**
- 5. Plot IC activations**



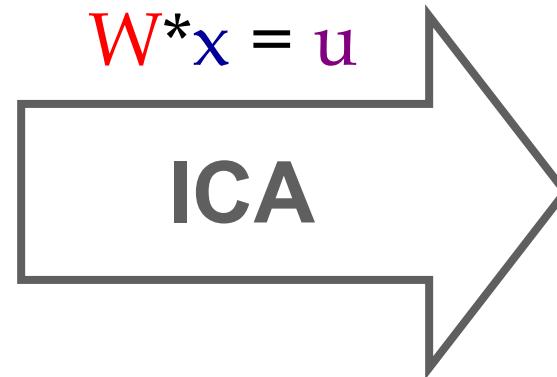
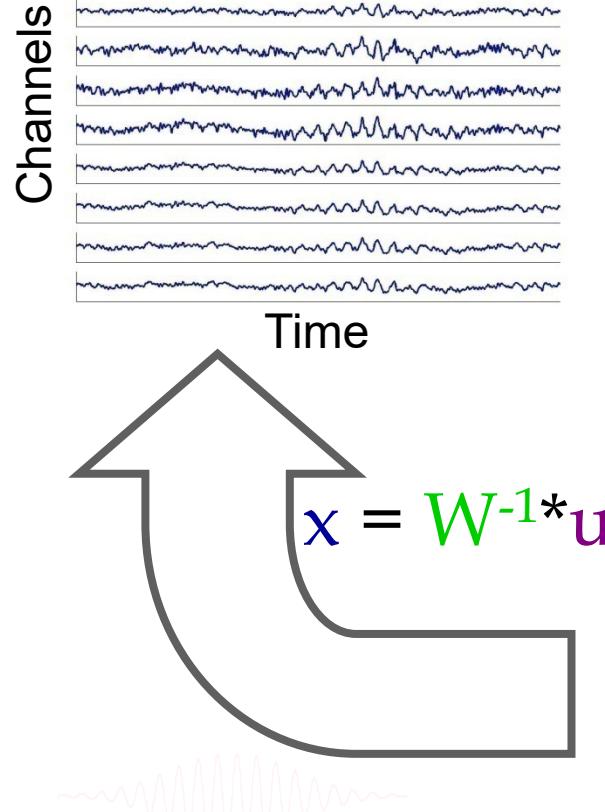
# Independent Component Analysis



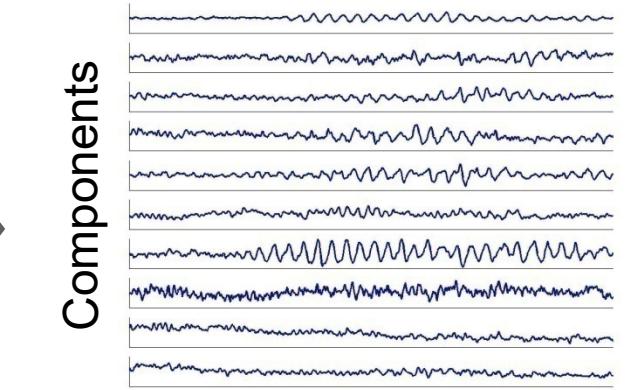
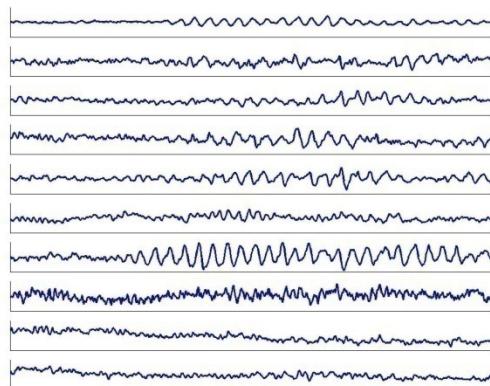
$x$  = scalp EEG

$W$  = unmixing matrix

$u$  = sources

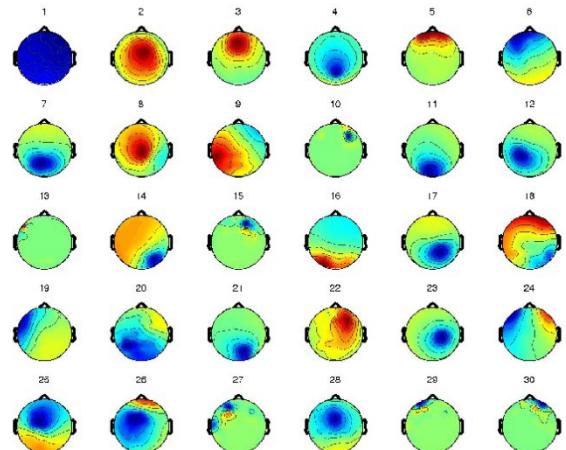


$u$  = sources



Time  
 $W^{-1}$  (scalp projections)

\*



ICA Components

# Evaluating ICs



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- 2. Run ICA**
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- 5. Plot IC activations**

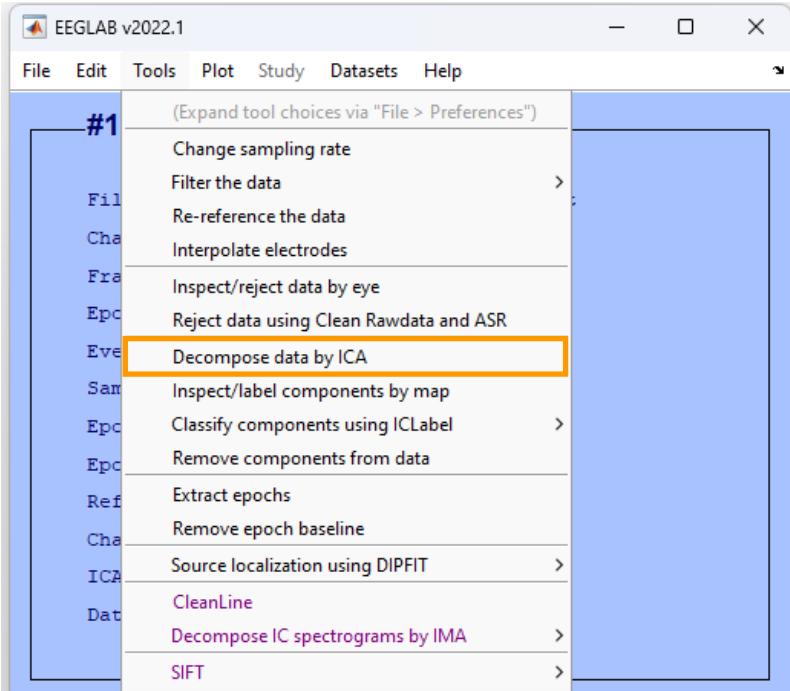
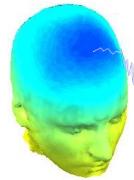


# “Secrets” to a good ICA decomposition



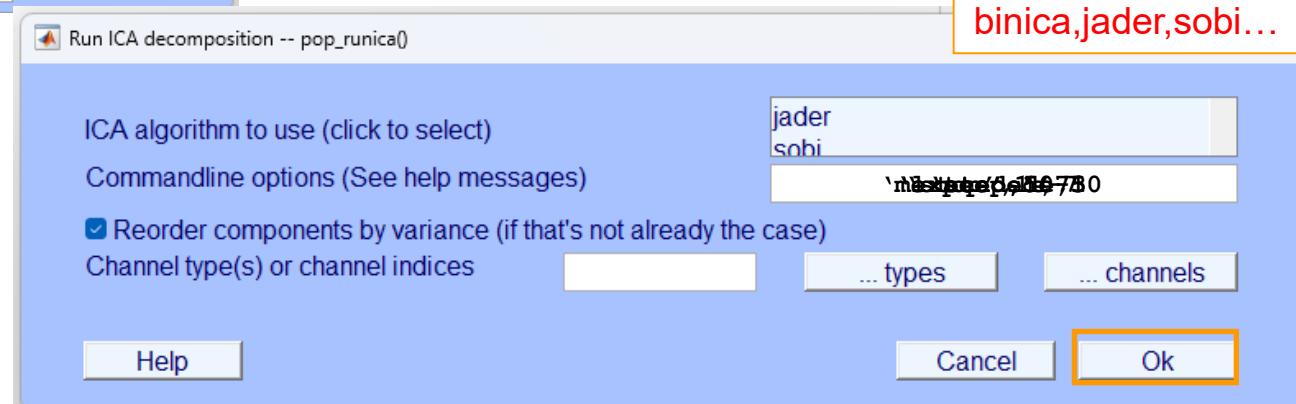
- **Garbage in... garbage out (it's not magic)**
- **Remove large, non-stereotyped artifacts**
- **Do you have enough data? (based mostly on time, not frames)**
  - \* ~30 min of data for 60-70 channels, ~60 min for > 200 channels
- **High-pass filter to remove slow drifts**
  - \* low-pass or notch filters are usually unnecessary
- **Remove bad channels**
- **Data must be in double precision (not single)**

# Runica options

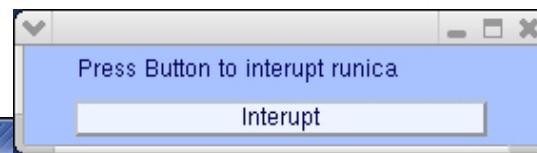


<u>Option</u>	<u>Default</u>	<u>Comments</u>
'extended'	0	1 is recommended to find sub-gaussians
'stop'	1e-7	final weight change → stop
'lrate'	determined from data	too small → too long... too large → wts blow up
'maxsteps'	512	more channels → more steps
'pca'	0 or EEG.nbchan	Decompose only a principal data subspace

Other algorithms:  
binica,jader,sobi...



# Runica progress...



csh  
Input data size [33,133175] = 33 channels, 133175 frames/nFinding 33 ICA components using extended ICA.

Kurtosis will be calculated initially every 1 blocks using 6000 data points.

Decomposing 122 frames per ICA weight ((1089)^2 = 133175 weights, Initial learning rate will be 0.001, block size

Learning rate will be multiplied by 0.98 whenever angledelta >= 60 deg.

More than 32 channels: default stopping weight change 1E-7

Training will end when wchange < 1e-07 or after 512 steps.

Online bias adjustment will be used.

Removing mean of each channel ...

Final training data range: -171.806 to 179.094

Computing the sphering matrix...

Starting weights are the identity matrix ...

Sphering the data ...

Beginning ICA training ... first training step may be slow ...

step 1 - lrate 0.001000, wchange 16.85061324, angledelta 0.0 deg

step 2 - lrate 0.001000, wchange 0.26760405, angledelta 0.0 deg

step 3 - lrate 0.001000, wchange 0.79058323, angledelta 104.0 deg

step 4 - lrate 0.000980, wchange 0.66700031, angledelta 147.2 deg

step 5 - lrate 0.000960, wchange 0.62849071, angledelta 146.5 deg

step 6 - lrate 0.000941, wchange 0.73967955, angledelta 150.7 deg

step 7 - lrate 0.000922, wchange 0.73727229, angledelta 151.6 deg

step 8 - lrate 0.000904, wchange 0.74051387, angledelta 137.9 deg

step 9 - lrate 0.000886, wchange 0.74536137, angledelta 156.0 deg

step 10 - lrate 0.000868, wchange 0.72101402, angledelta 143.7 deg

step 11 - lrate 0.000851, wchange 0.14690114, angledelta 102.5 deg

step 12 - lrate 0.000834, wchange 0.11822100, angledelta 114.3 deg

step 13 - lrate 0.000817, wchange 0.75552966, angledelta 100.6 deg

step 14 - lrate 0.000801, wchange 0.26739750, angledelta 109.1 deg

step 15 - lrate 0.000785, wchange 0.12123251, angledelta 94.2 deg

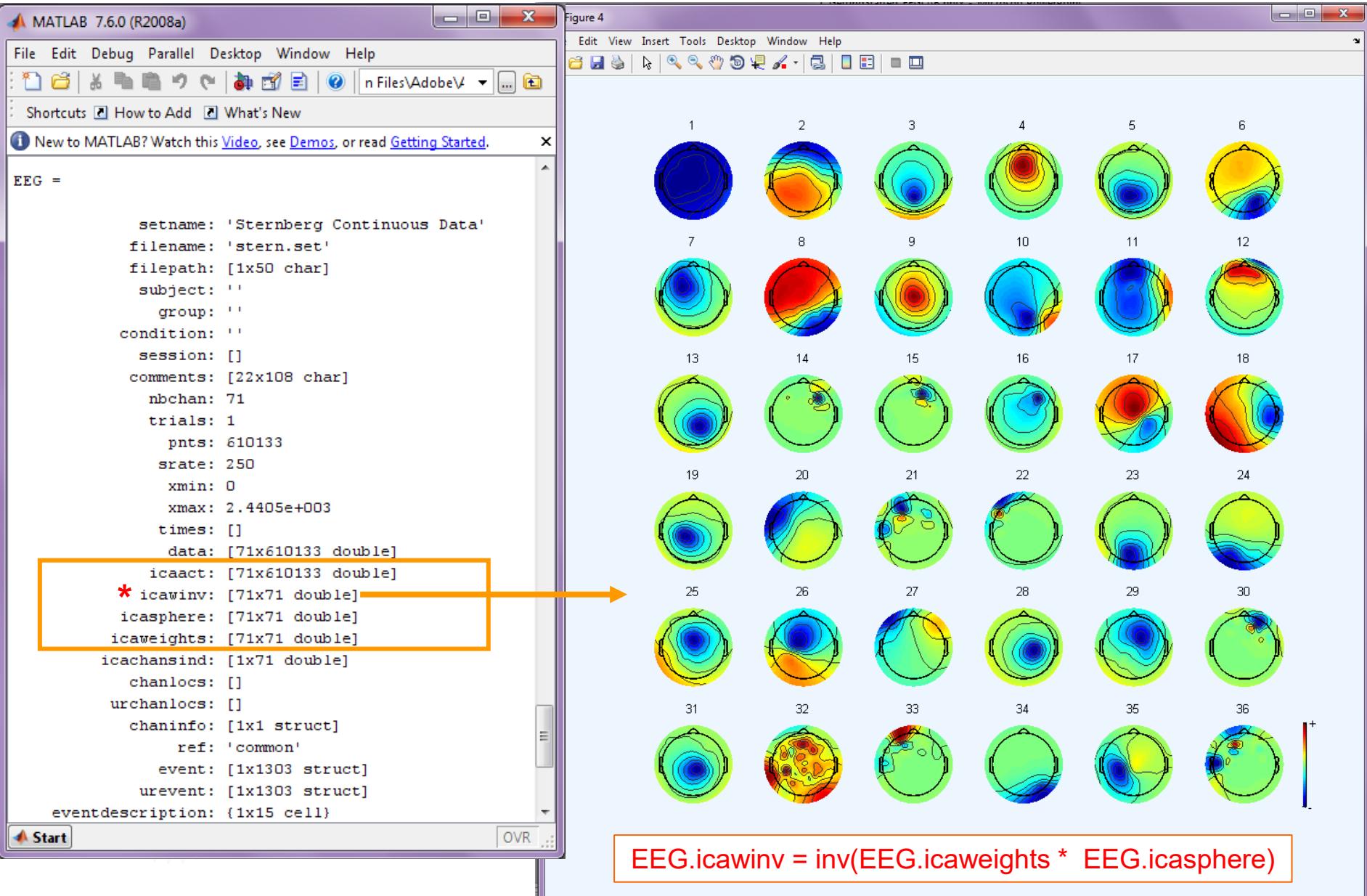
step 16 - lrate 0.000769, wchange 0.10285606, angledelta 110.7 deg

step 17 - lrate 0.000754, wchange 0.09770499, angledelta 118.6 deg

step 18 - lrate 0.000739, wchange 0.09544428, angledelta 117.1 deg

csh  
step 241 - lrate 0.000002, wchange 0.00000082, angledelta 101.5 deg  
step 242 - lrate 0.000001, wchange 0.00000061, angledelta 96.1 deg  
step 243 - lrate 0.000001, wchange 0.00000057, angledelta 97.5 deg  
step 244 - lrate 0.000001, wchange 0.00000054, angledelta 93.7 deg  
step 245 - lrate 0.000001, wchange 0.00000055, angledelta 100.3 deg  
step 246 - lrate 0.000001, wchange 0.00000047, angledelta 96.9 deg  
step 247 - lrate 0.000001, wchange 0.00000046, angledelta 91.3 deg  
step 248 - lrate 0.000001, wchange 0.00000045, angledelta 101.5 deg  
step 249 - lrate 0.000001, wchange 0.00000041, angledelta 103.1 deg  
step 250 - lrate 0.000001, wchange 0.00000036, angledelta 95.5 deg  
step 251 - lrate 0.000001, wchange 0.00000033, angledelta 92.1 deg  
step 252 - lrate 0.000001, wchange 0.00000029, angledelta 97.4 deg  
step 253 - lrate 0.000001, wchange 0.00000030, angledelta 95.8 deg  
step 254 - lrate 0.000001, wchange 0.00000023, angledelta 94.2 deg  
step 255 - lrate 0.000001, wchange 0.00000023, angledelta 97.6 deg  
step 256 - lrate 0.000001, wchange 0.00000023, angledelta 97.1 deg  
step 257 - lrate 0.000001, wchange 0.00000021, angledelta 92.0 deg  
step 258 - lrate 0.000001, wchange 0.00000020, angledelta 99.1 deg  
step 259 - lrate 0.000001, wchange 0.00000019, angledelta 95.0 deg  
step 260 - lrate 0.000001, wchange 0.00000015, angledelta 98.3 deg  
step 261 - lrate 0.000001, wchange 0.00000014, angledelta 99.0 deg  
step 262 - lrate 0.000001, wchange 0.00000014, angledelta 94.3 deg  
step 263 - lrate 0.000001, wchange 0.00000013, angledelta 95.4 deg  
step 264 - lrate 0.000001, wchange 0.00000012, angledelta 94.1 deg  
step 265 - lrate 0.000001, wchange 0.00000011, angledelta 96.1 deg  
step 266 - lrate 0.000001, wchange 0.00000010, angledelta 94.8 deg  
step 267 - lrate 0.000001, wchange 0.00000010, angledelta 94.5 deg  
step 268 - lrate 0.000001, wchange 0.00000010, angledelta 97.7 deg  
step 269 - lrate 0.000001, wchange 0.00000008, angledelta 95.1 deg  
Sorting components in descending order of mean projected variance ...  
Permuting the activation wave forms ...  
>>  
>>

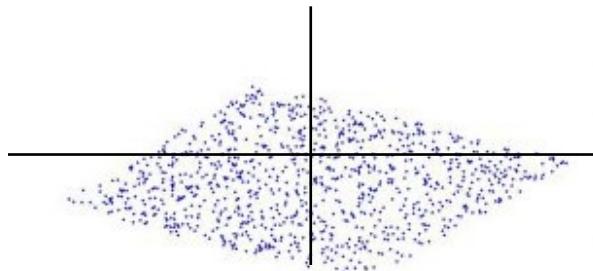
# ICA weights in EEG structure



# Explanation of "sphering"

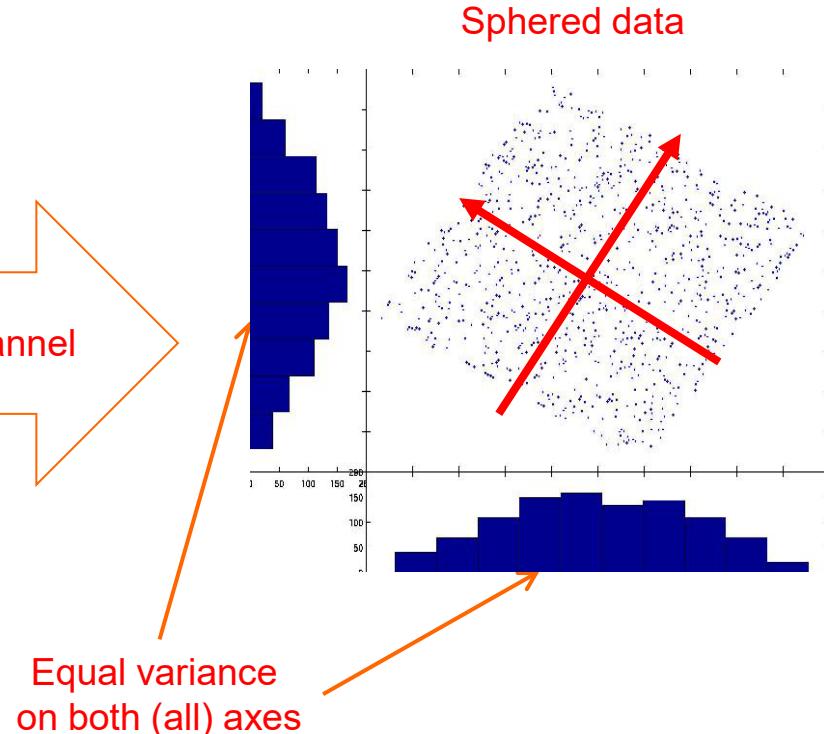


Original data



"Sphering":  
Remove channel  
correlations

Like ICA, sphering is also a linear operation, so re-projecting to original space simply requires multiplying with the weight matrix

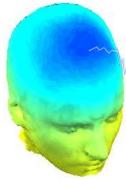


Equal variance  
on both (all) axes

For more explanation, see:

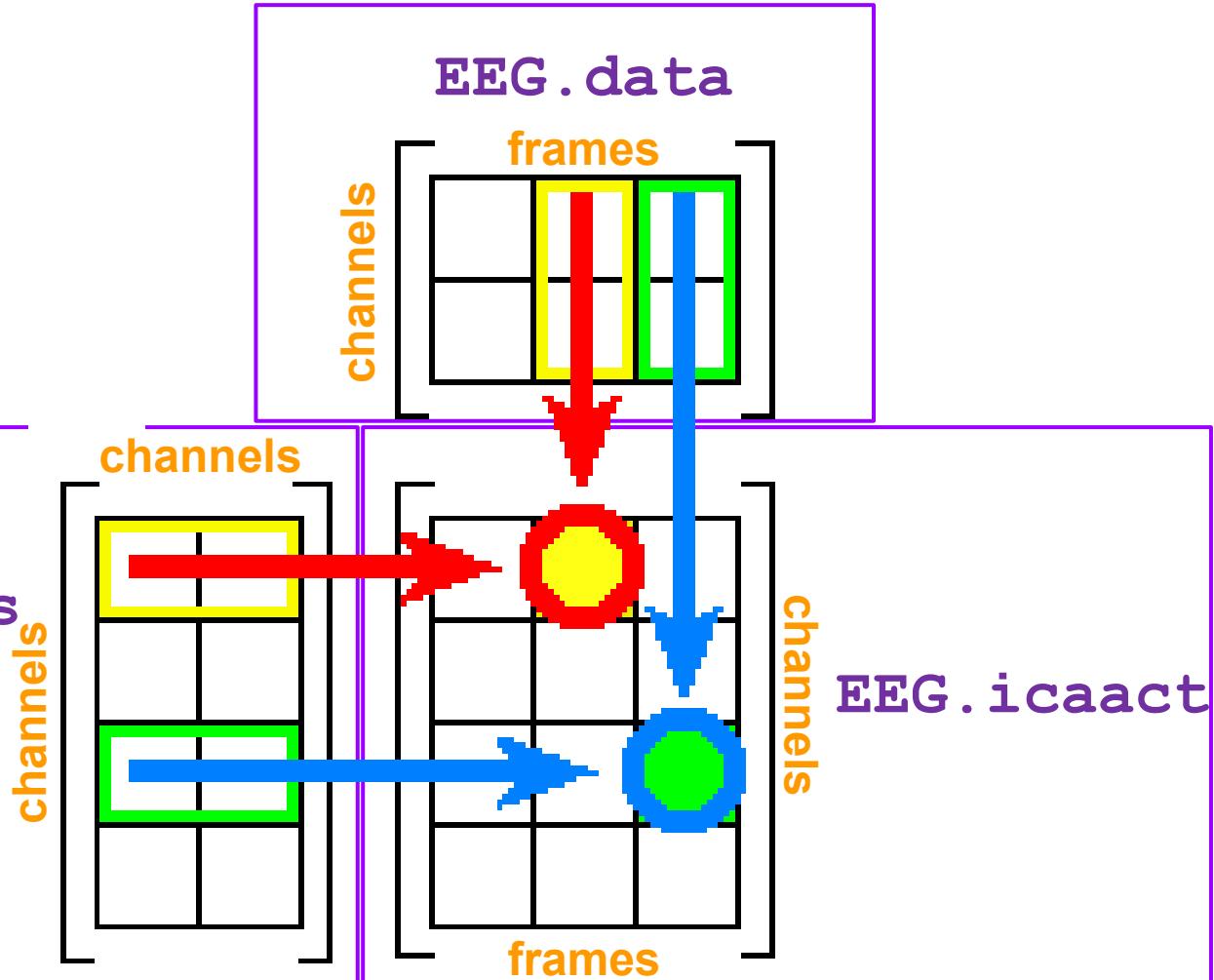
and [http://sccn.ucsd.edu/wiki/Linear\\_Representations\\_and\\_Basis\\_Vectors](http://sccn.ucsd.edu/wiki/Linear_Representations_and_Basis_Vectors)

# Applying ICA weights to EEG data



matrix  
multiplication

EEG.icaweights  
\*  
EEG.icasphere



# English → MATLAB



Source activation = **unmixing** \* Channel data

Channel data = **mixing (topo)** \* Source activation

`EEG.icaact = (EEG.icaweights*EEG.icasphere) * EEG.data`

`EEG.data = EEG.icawinv * EEG.icaact`



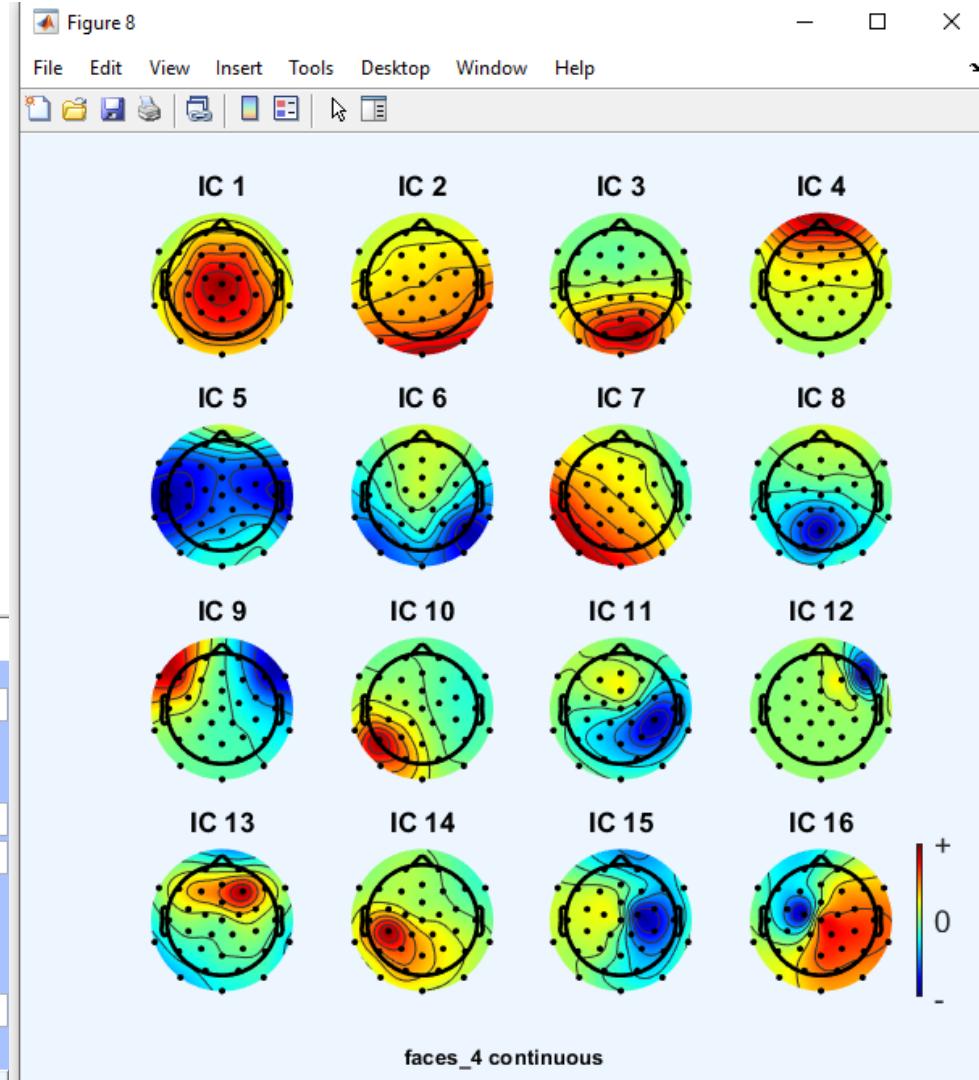
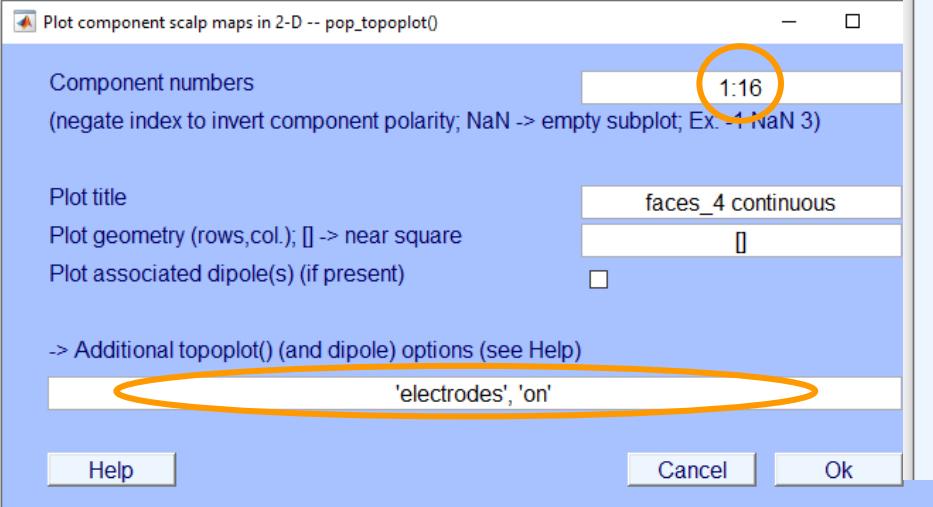
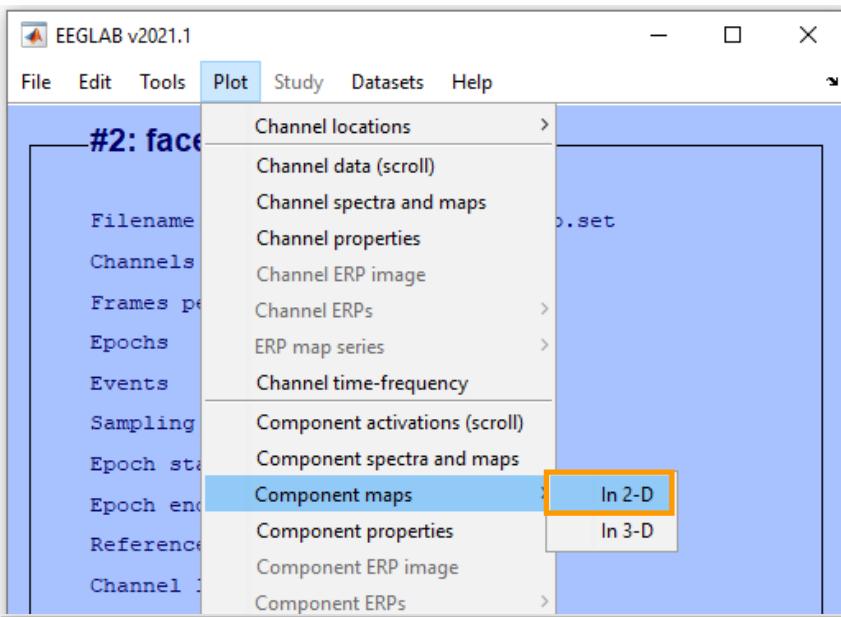
# Evaluating ICs



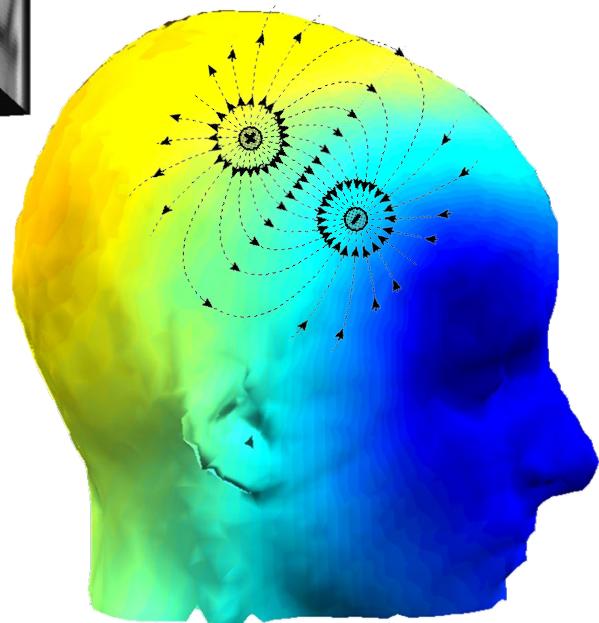
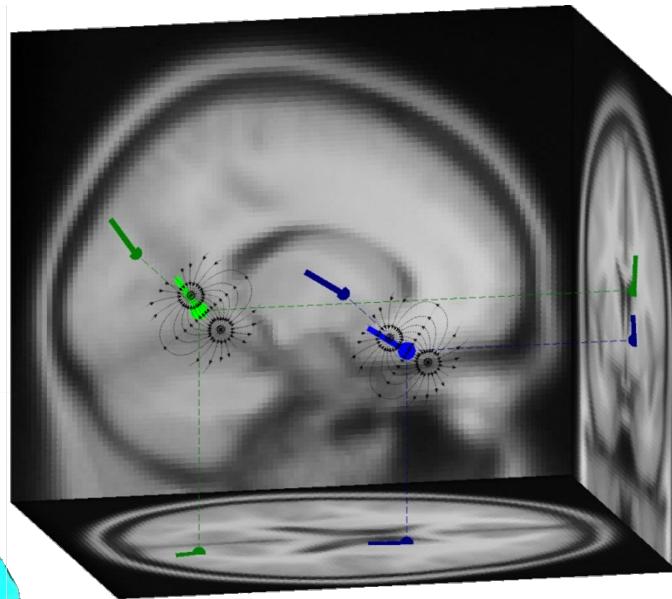
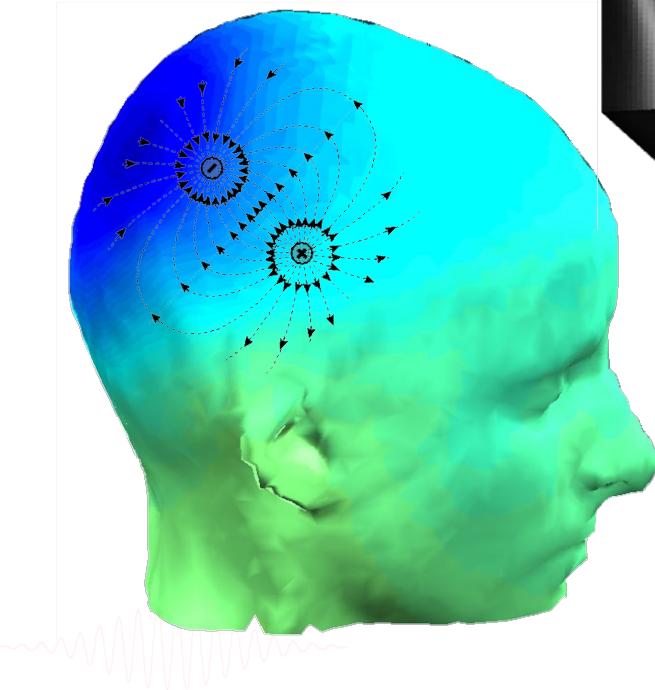
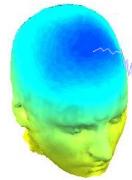
- 1. ICA introduction**
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- 5. Plot IC activations**



# Plot ICA scalp maps



# Single-dipole projections



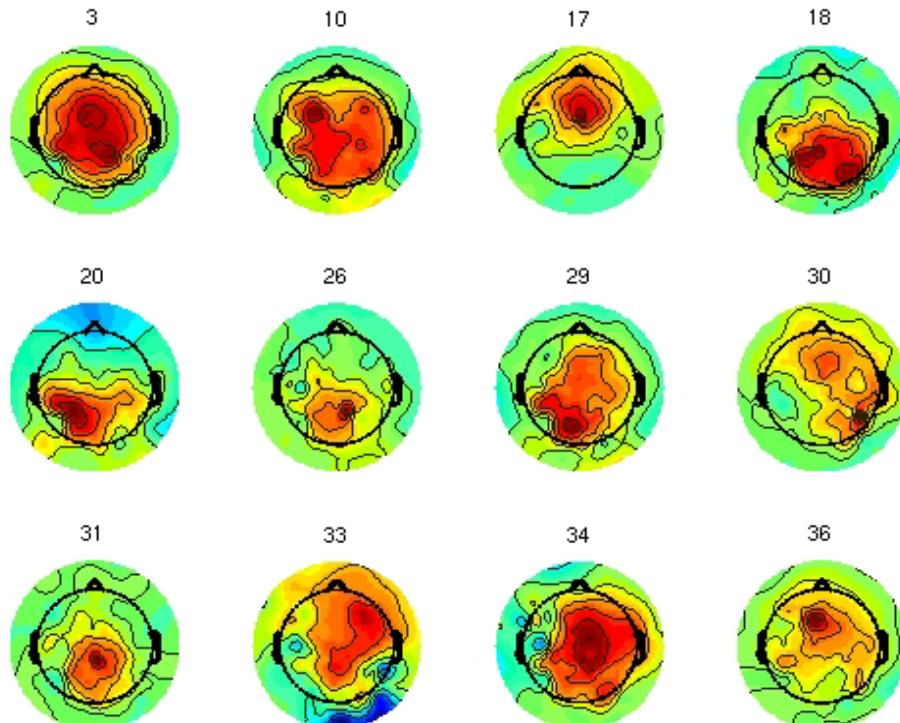
# Compare 'good' and 'bad' scalp maps



chaotic gradients

no clear patterns

INconsistent with single dipoles

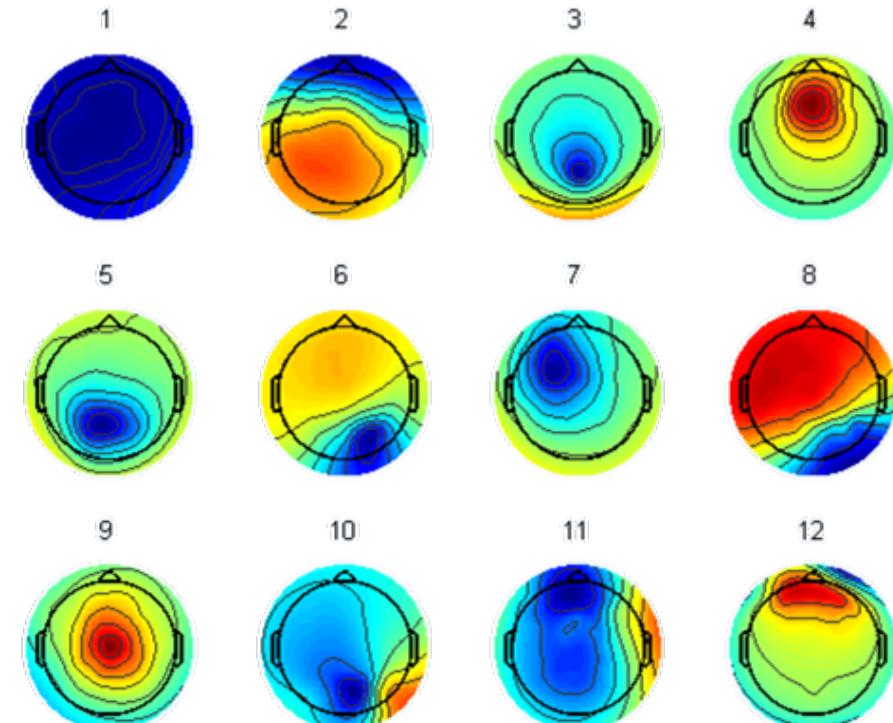


BAD ICA Components

smooth gradients

concentric rings (when radial)

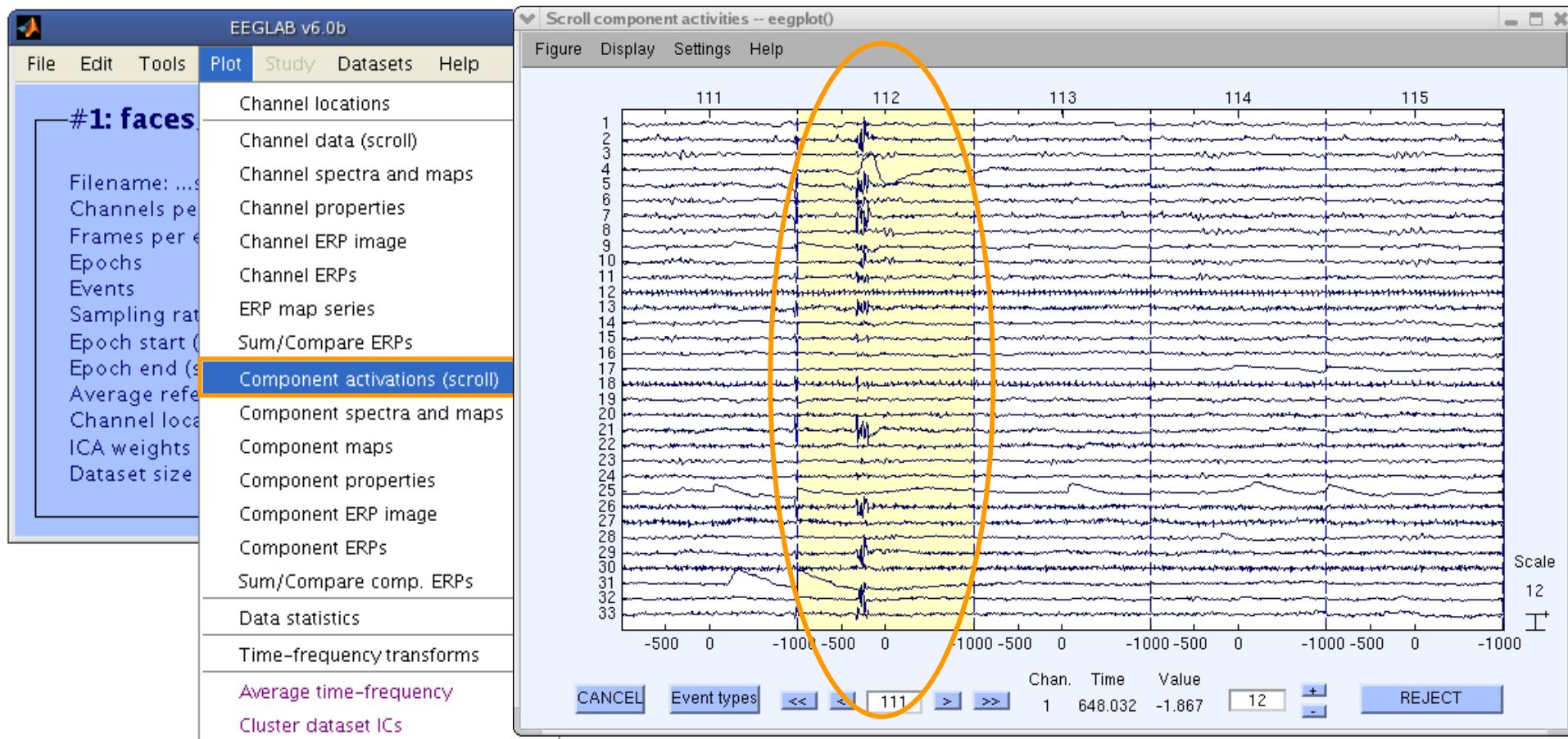
consistent with single dipoles



jo74 Sternberg Continuous



# Scroll component activities



Time periods that are not independent across ICs  
should be removed and ICA run again for better decomposition

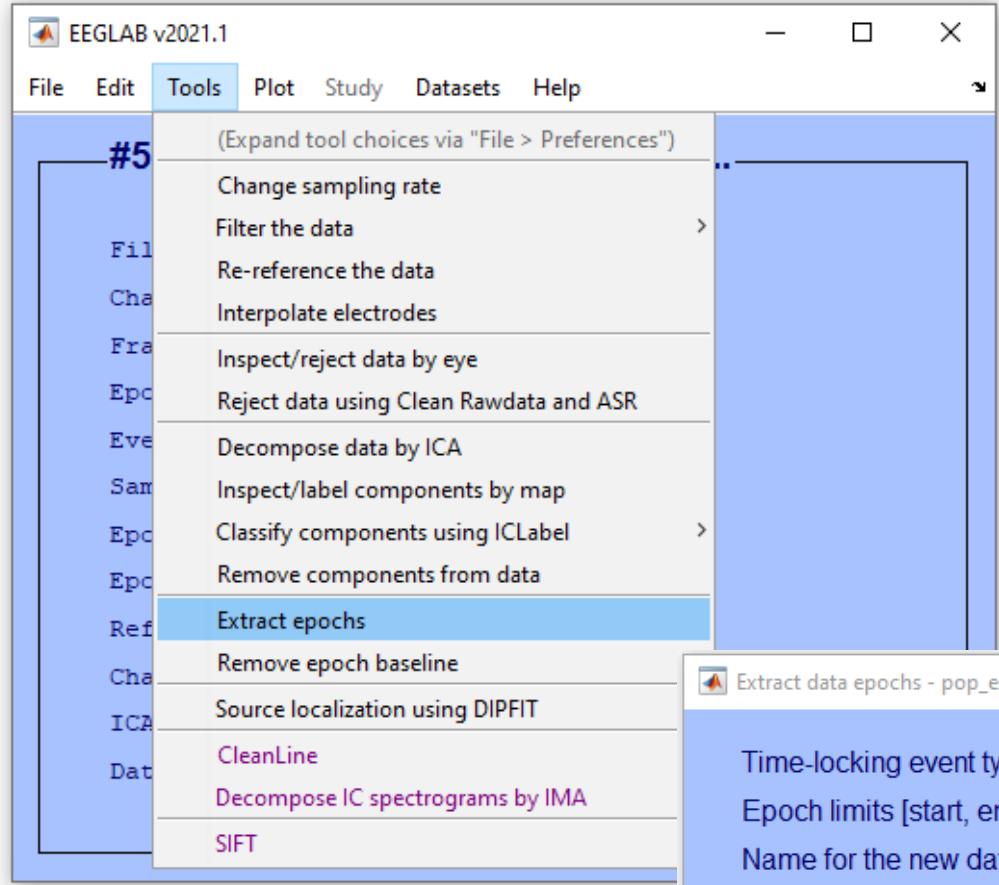
# Evaluating ICs



- 1. ICA introduction**
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# Extract epochs

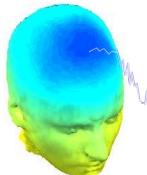


The image displays two overlapping dialog boxes. The top dialog is titled '(use shift|ctrl to select several)' and lists event types: boundary, bp1, bp4, face (which is selected), and object. The bottom dialog is titled 'Extract data epochs - pop\_epoch()' and contains the following fields:

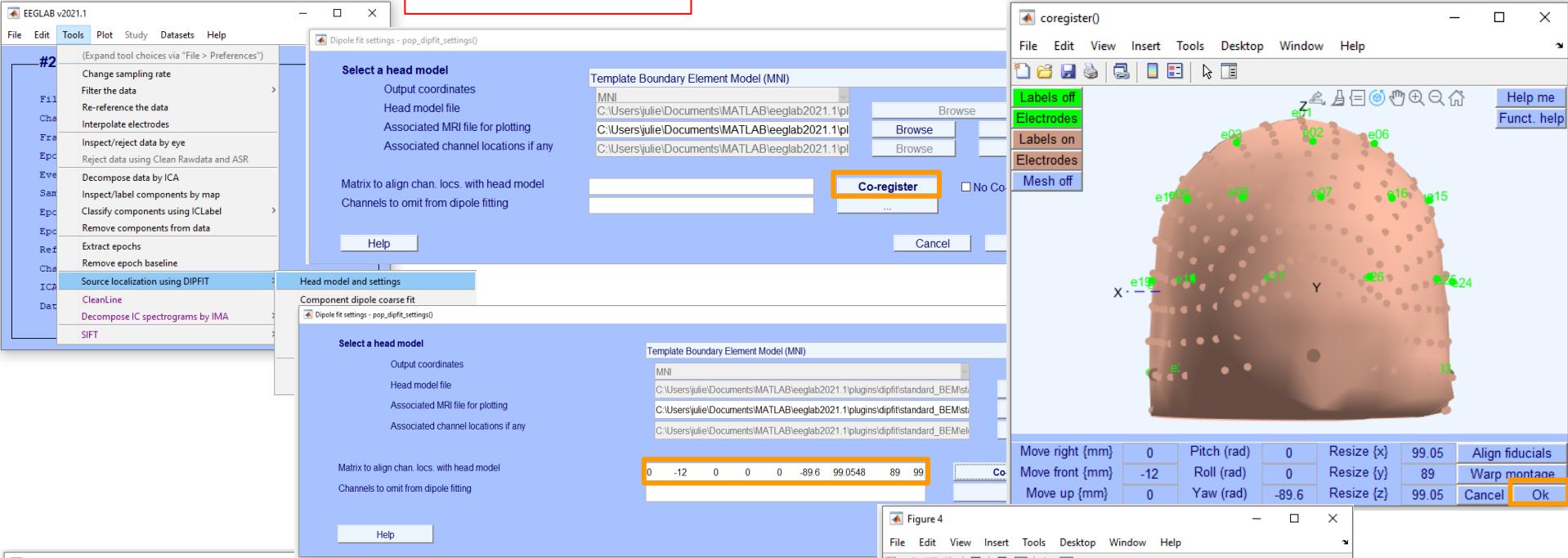
- Time-locking event type(s) ([] = all): face
- Epoch limits [start, end] in seconds: -1 2
- Name for the new dataset: faces\_4 continuous epochs
- Out-of-bounds EEG limits if any [min max]:

Buttons for both dialogs include 'Cancel' and 'Ok'. An orange arrow points from the 'face' entry in the selection list to the corresponding entry in the 'Extract data epochs' dialog.

# Dipole fitting



## 1. Head model



EEGLAB v2021.1

File Edit Tools Plot Study Datasets Help

#2

Source localization using DIPFIT

Dipole fit settings - pop\_dipfit\_settings()

Select a head model

Output coordinates  
Head model file  
Associated MRI file for plotting  
Associated channel locations if any

Matrix to align chan. locs. with head model  
Channels to omit from dipole fitting

Help

Coregister

Labels off  
Electrodes  
Labels on  
Electrodes  
Mesh off

Co-register

Cancel

Help

Component dipole coarse fit

Dipole fit settings - pop\_dipfit\_settings()

Select a head model

Output coordinates  
Head model file  
Associated MRI file for plotting  
Associated channel locations if any

Matrix to align chan. locs. with head model  
Channels to omit from dipole fitting

Help

Template Boundary Element Model (MNI)

MNI  
C:\Users\julie\Documents\MATLAB\eeglab2021.1\pl  
C:\Users\julie\Documents\MATLAB\eeglab2021.1\pl  
C:\Users\julie\Documents\MATLAB\eeglab2021.1\pl

Browse

Browse

Browse

Co-register

Cancel

Move right {mm} 0 Pitch (rad) 0 Resize {x} 99.05 Align fiducials

Move front {mm} -12 Roll (rad) 0 Resize {y} 89 Warp montage

Move up {mm} 0 Yaw (rad) -89.6 Resize {z} 99.05

Figure 4

File Edit View Insert Tools Desktop Window Help

33 dipoles:

Plot one  
KeepNext  
Next  
Prev  
KeepPrev

Comp: 1  
RV: 3.22%  
X tal: -3  
Y tal: -6  
Z tal: 14

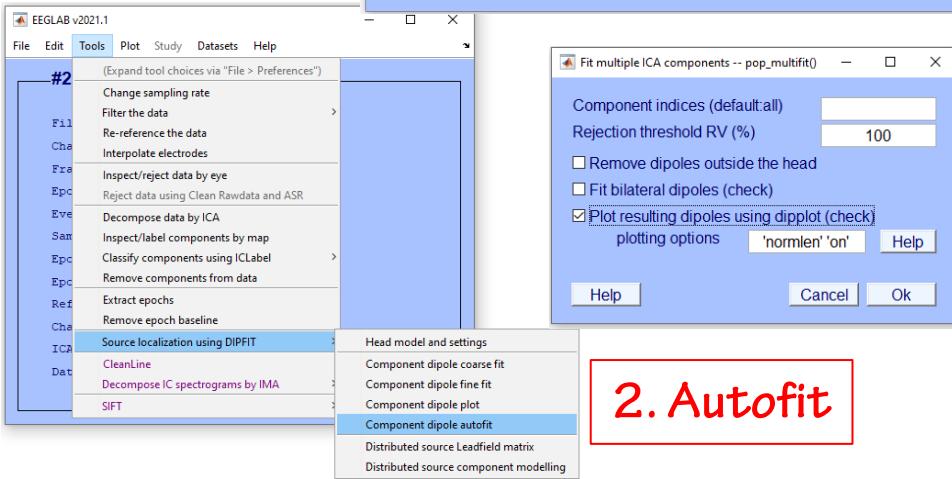
Display:  
Mesh on  
Tight view  
Sagittal view  
Coronal view  
Top view  
No controls

X e01 e02 e06 e03 e08 e09 e07 e16 e15 e19 e18 e14 e17 e13 e24 e23 e22 e21 e20 e12 e11 e10 e05 e04 e00 e01 e02 e06 e03 e08 e09 e07 e16 e15 e19 e18 e14 e17 e13 e24 e23 e22 e21 e20 e12 e11 e10 e05 e04 e00

Y e01 e02 e06 e03 e08 e09 e07 e16 e15 e19 e18 e14 e17 e13 e24 e23 e22 e21 e20 e12 e11 e10 e05 e04 e00 e01 e02 e06 e03 e08 e09 e07 e16 e15 e19 e18 e14 e17 e13 e24 e23 e22 e21 e20 e12 e11 e10 e05 e04 e00

Z e01 e02 e06 e03 e08 e09 e07 e16 e15 e19 e18 e14 e17 e13 e24 e23 e22 e21 e20 e12 e11 e10 e05 e04 e00 e01 e02 e06 e03 e08 e09 e07 e16 e15 e19 e18 e14 e17 e13 e24 e23 e22 e21 e20 e12 e11 e10 e05 e04 e00

## 2. Autofit



EEGLAB v2021.1

File Edit Tools Plot Study Datasets Help

#2

Source localization using DIPFIT

Fit multiple ICA components -- pop\_multifit()

Component indices (default:all)

Rejection threshold RV (%) 100

Remove dipoles outside the head

Fit bilateral dipoles (check)

Plot resulting dipoles using diplot (check)

plotting options 'normlen' 'on'

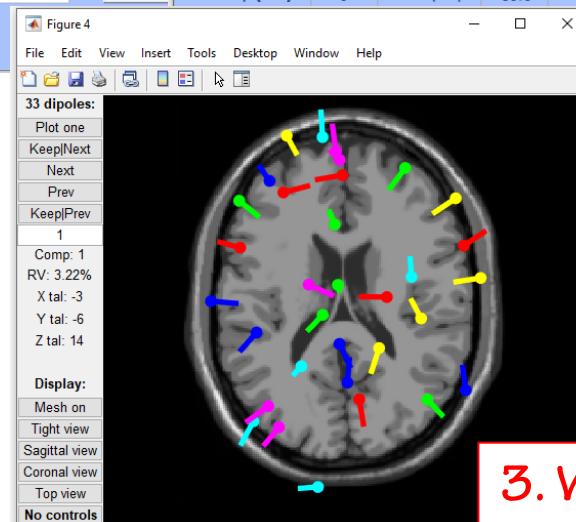
Help Cancel Ok

Head model and settings

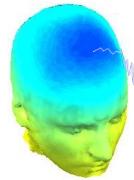
Component dipole coarse fit  
Component dipole fine fit  
Component dipole plot  
Component dipole autofit

Distributed source Leadfield matrix  
Distributed source component modelling

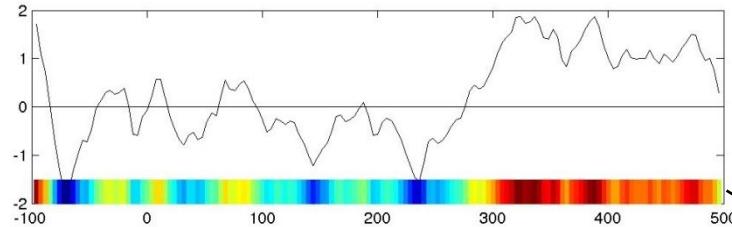
## 3. View dipoles



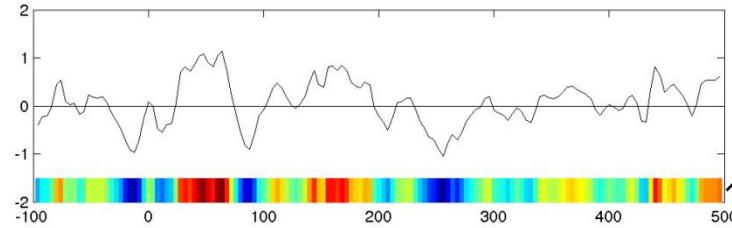
# ERP Image basics



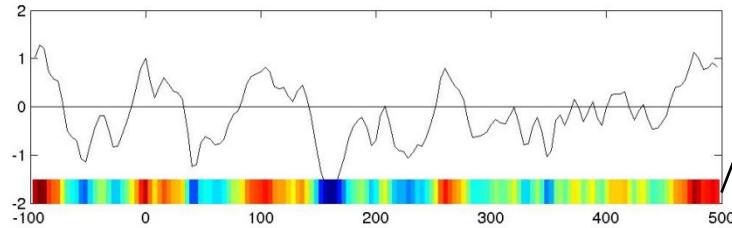
Trial 1



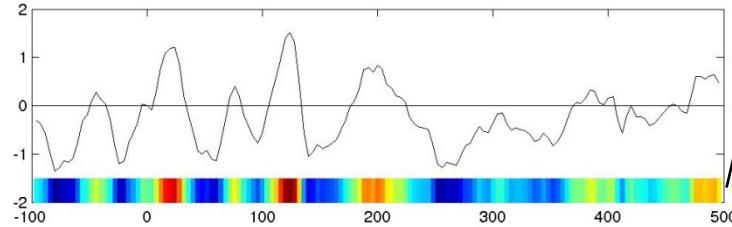
Trial 2



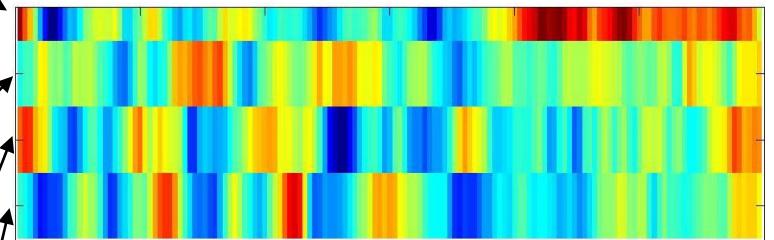
Trial 3



Trial 4



ERP Image



by default, sorted by  
time-on-task  
(1<sup>st</sup> trial, 2<sup>nd</sup> trial, ...)

# ERP Image basics

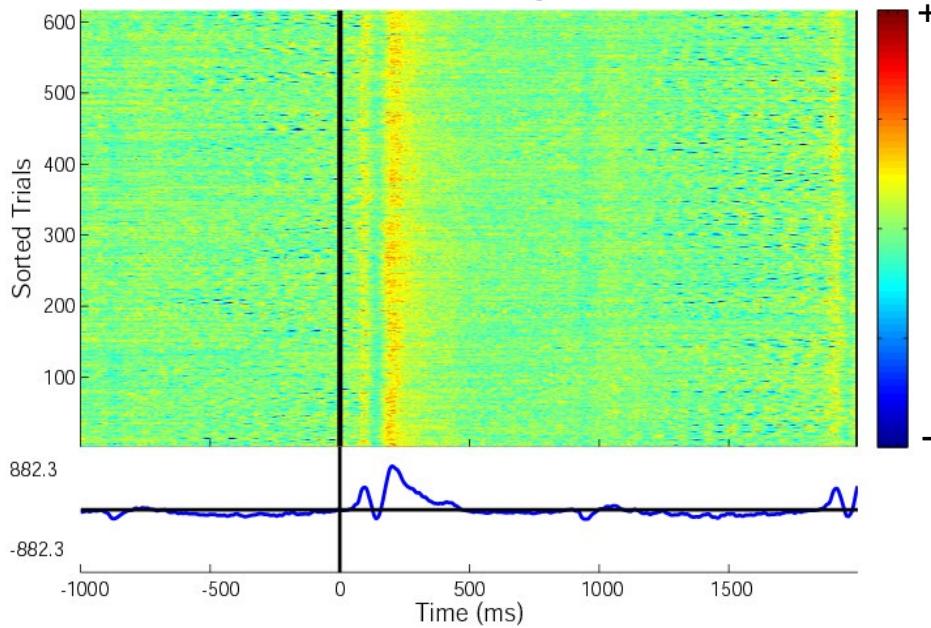
Trial 1:



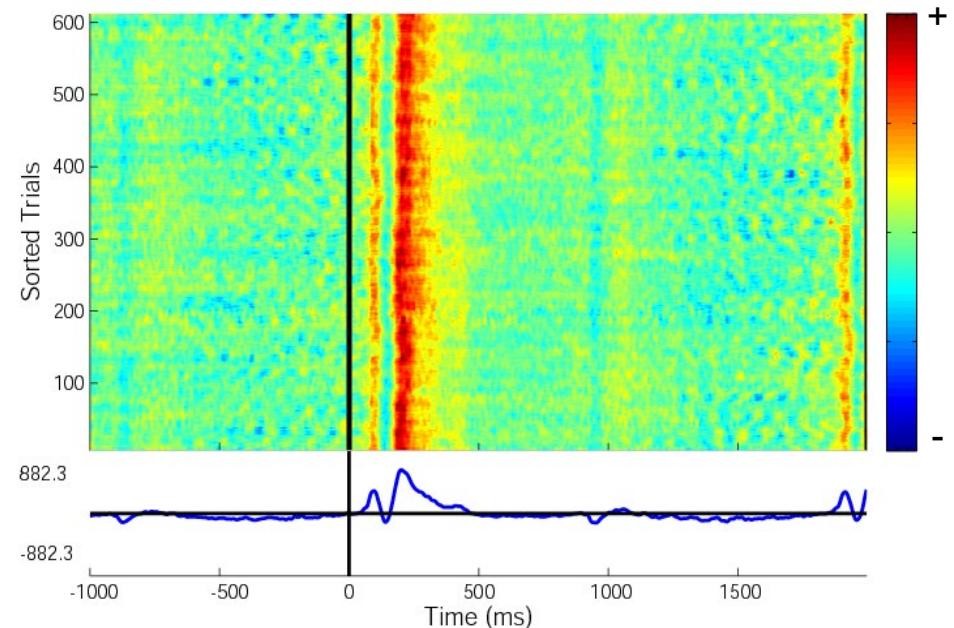
Trial 2:



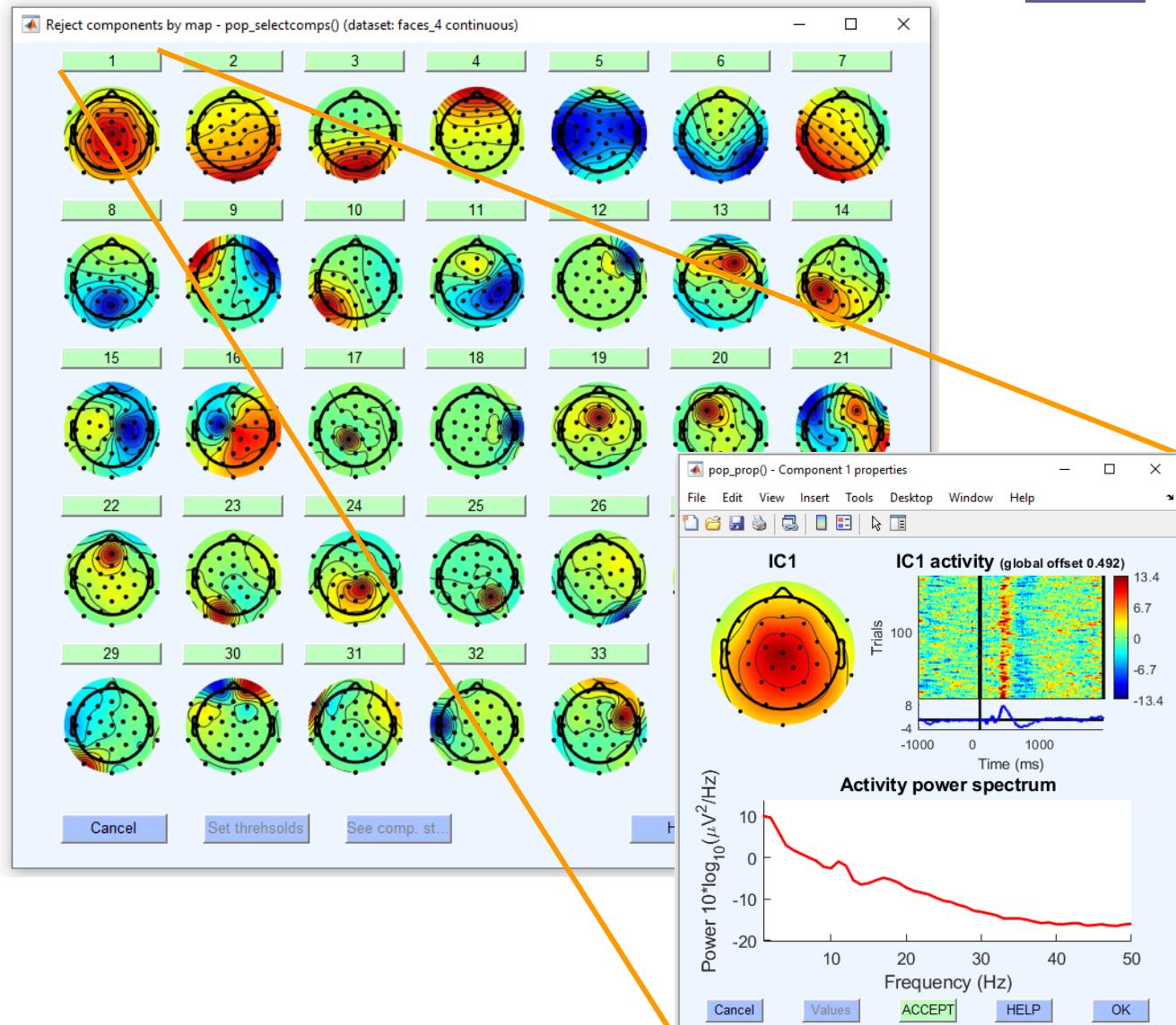
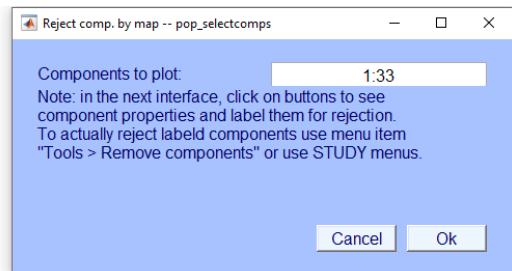
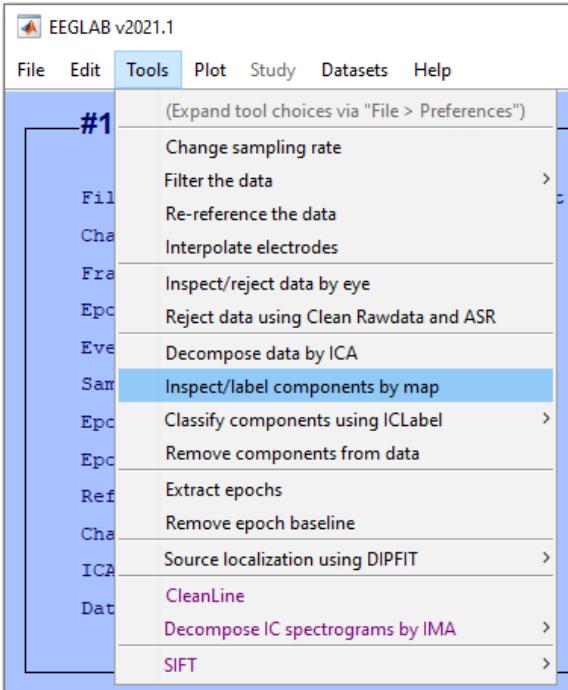
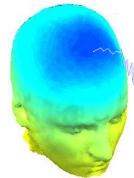
No Smoothing



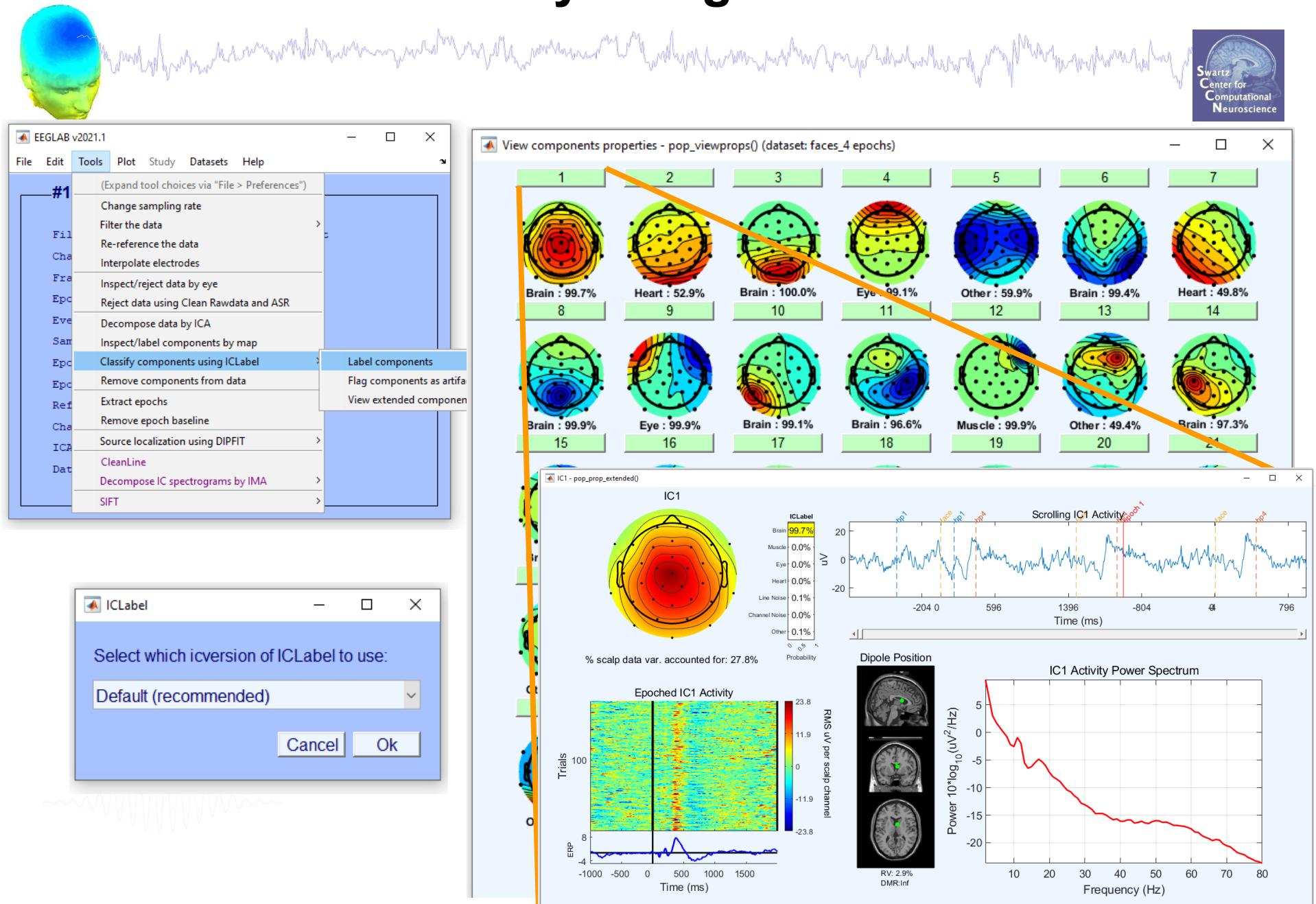
Smoothed across 10 Trials



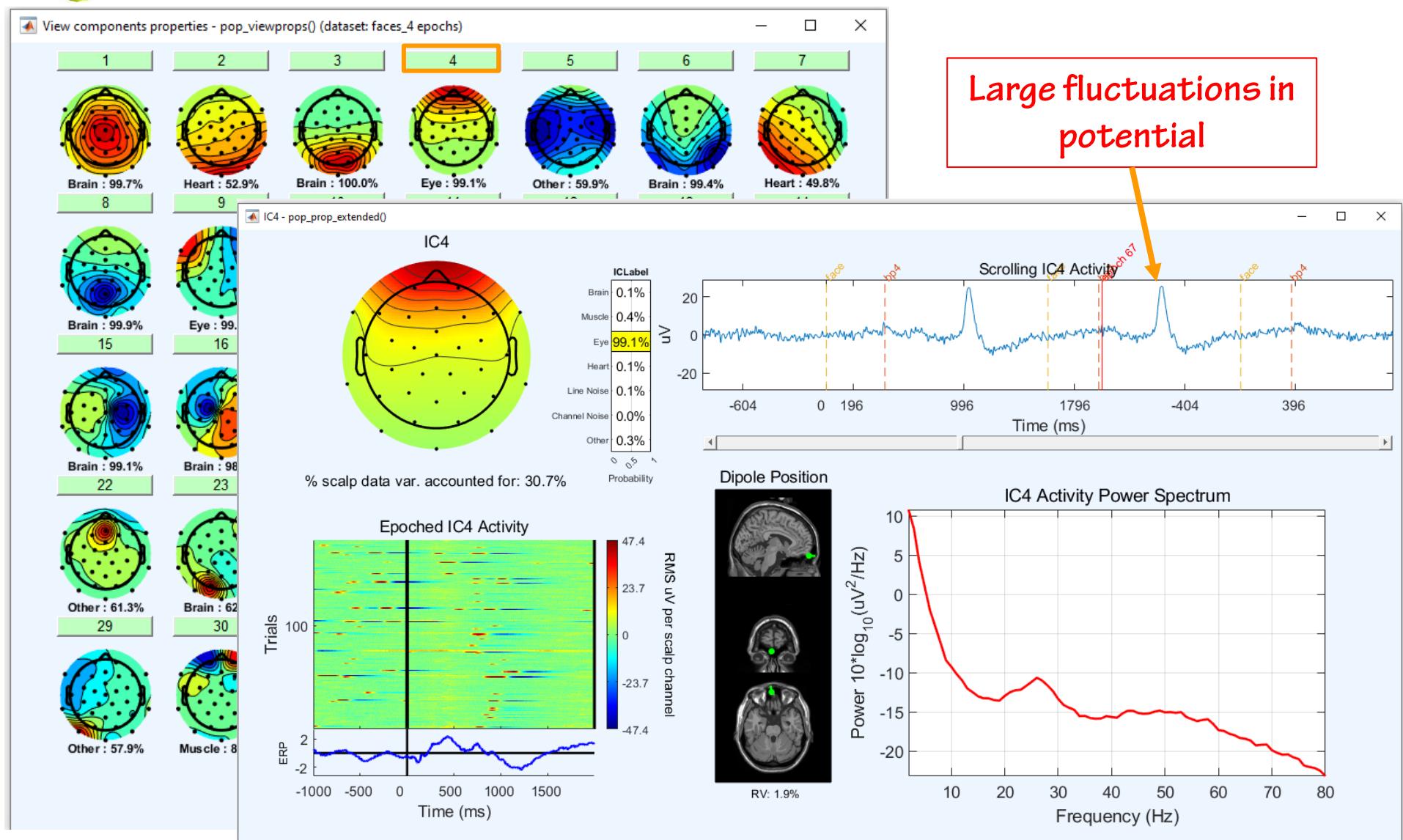
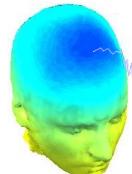
# Evaluate ICs



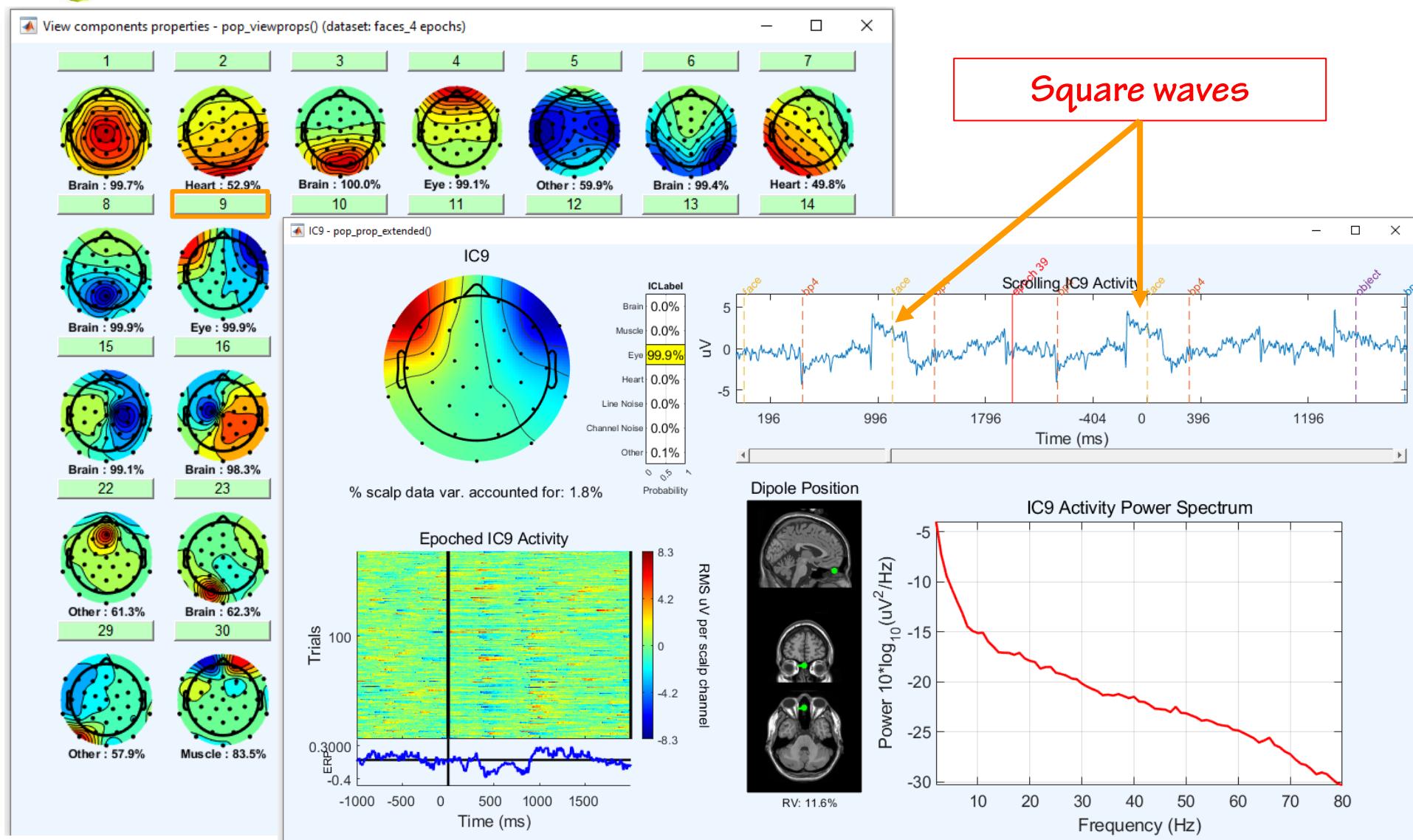
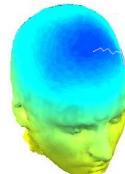
# Classify using ICLabel



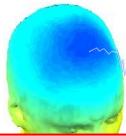
# IC 4 – eyeblink



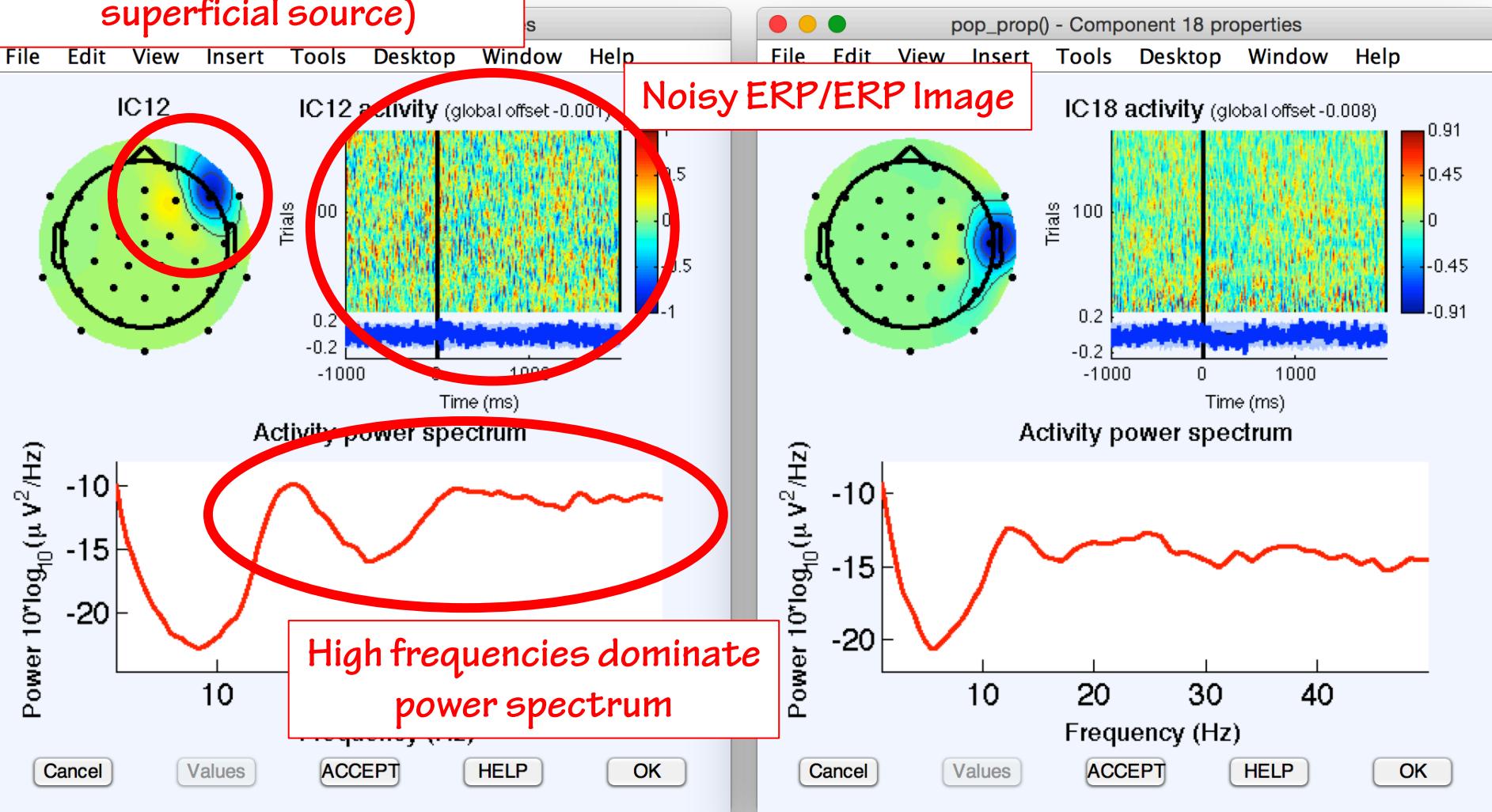
# IC 9 – lateral eye movement



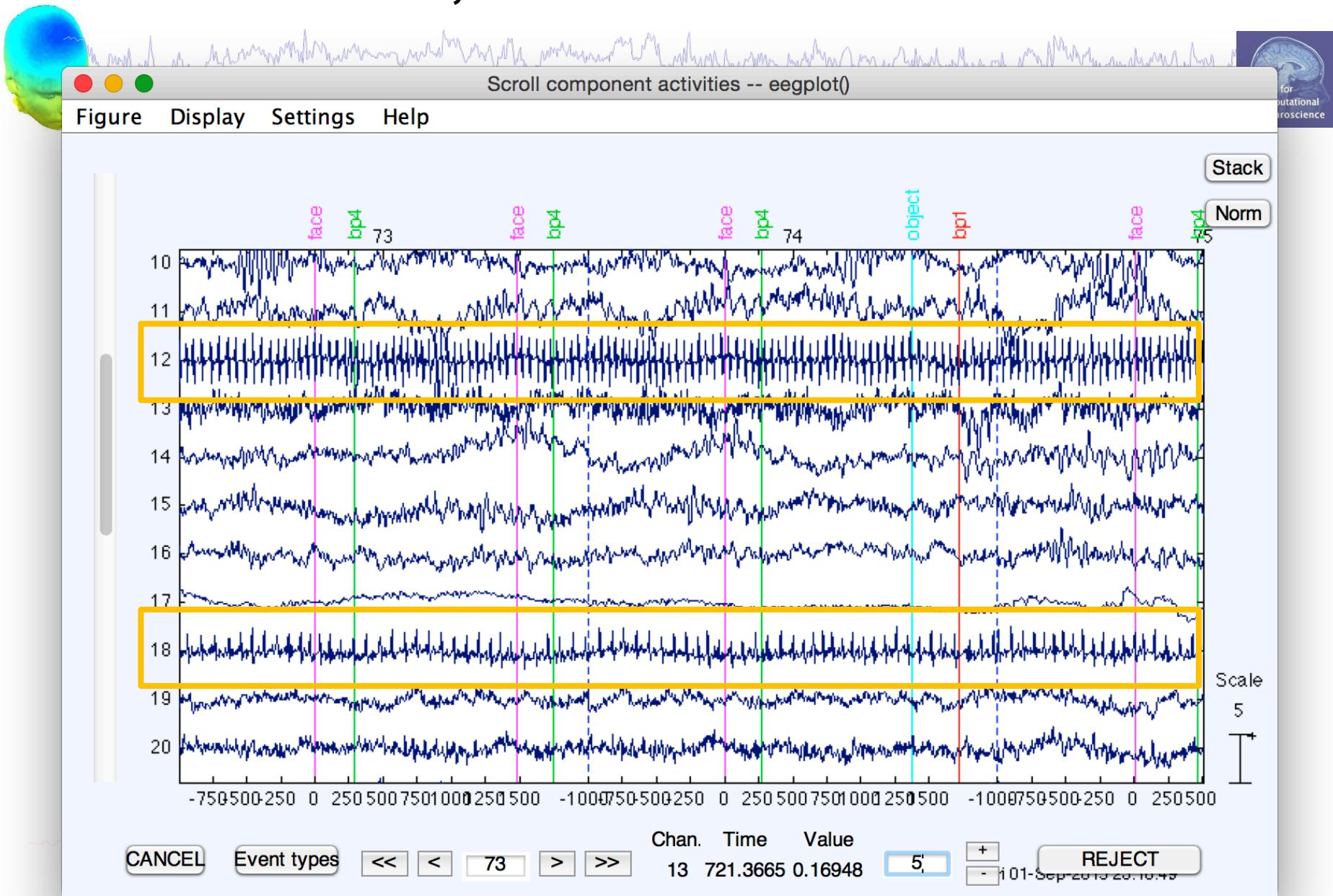
# ICs 12, 18 – Muscle



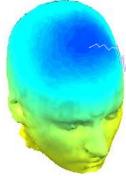
Narrowly spaced dipolar topography (consistent with superficial source)



# ICs 12, 18 Activation – Muscle



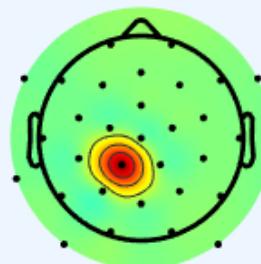
# IC 17, 25 – Bad channels



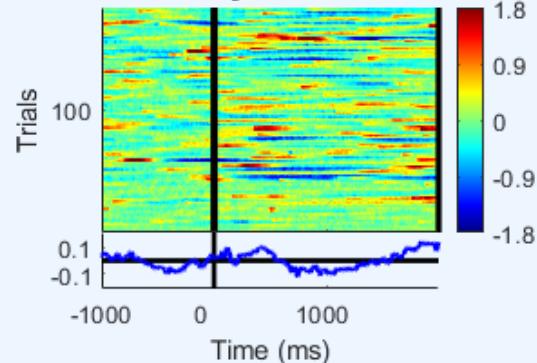
Punctate topography  
(single channel)

Sporadic epoch activity  
(sometimes just a single large spike)

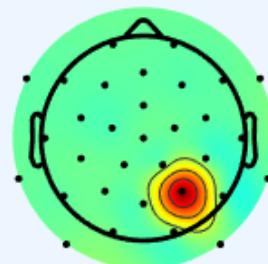
IC17



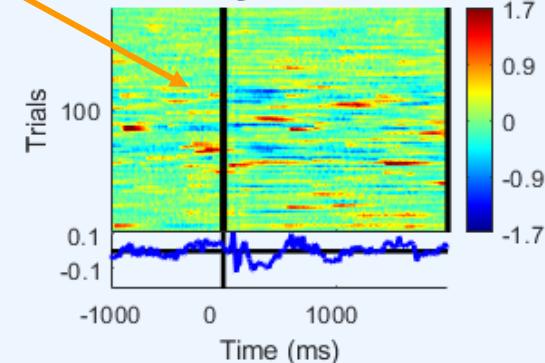
IC17 activity (global offset 0.014)



IC25



IC25 activity (global offset -0.006)



Power  $10 \log_{10} (\mu\text{V}^2/\text{Hz})$

Frequency (Hz)

Cancel

Values

ACCEPT

HELP

OK

Power  $10 \log_{10} (\mu\text{V}^2/\text{Hz})$

Frequency (Hz)

Cancel

Values

ACCEPT

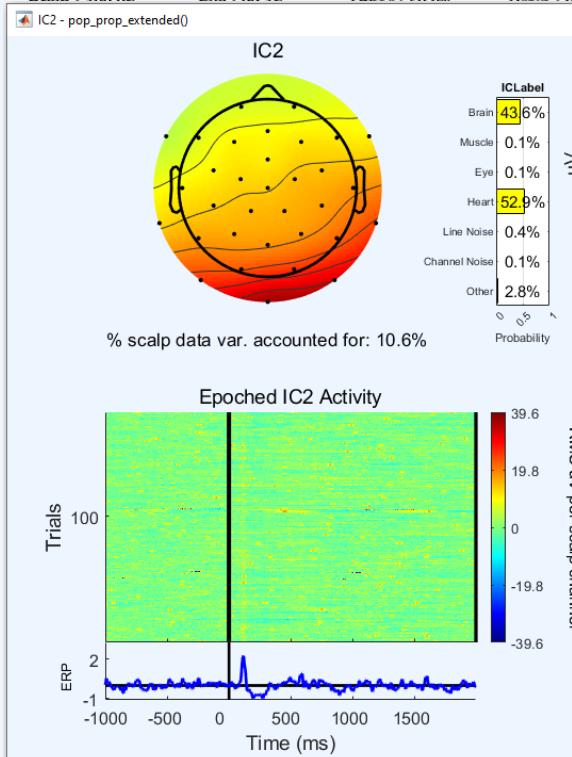
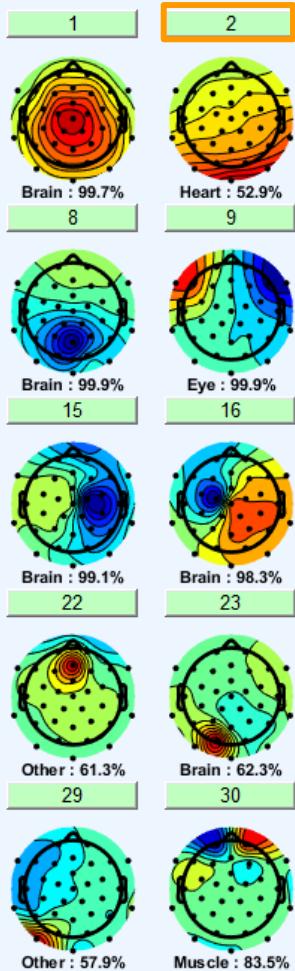
HELP

OK

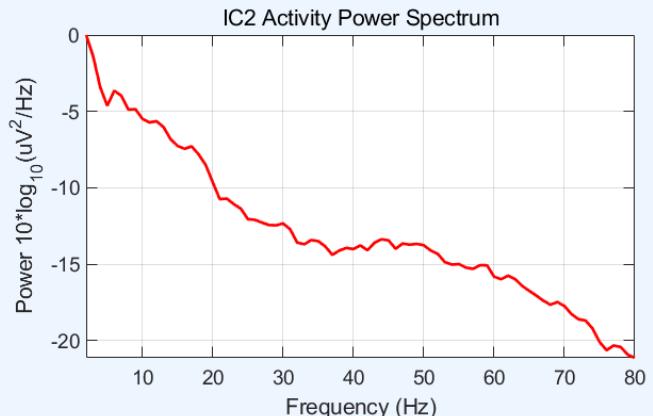
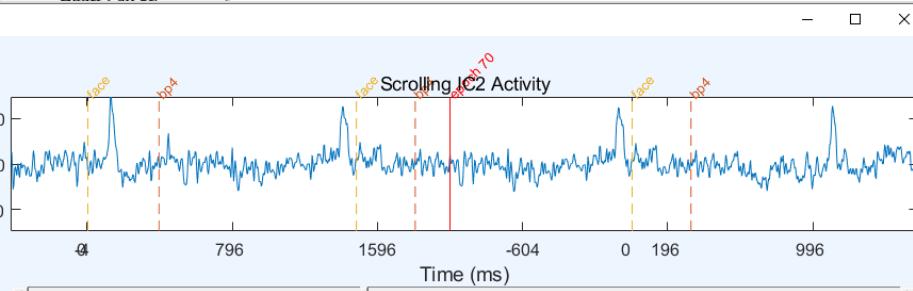
# Cardiac IC



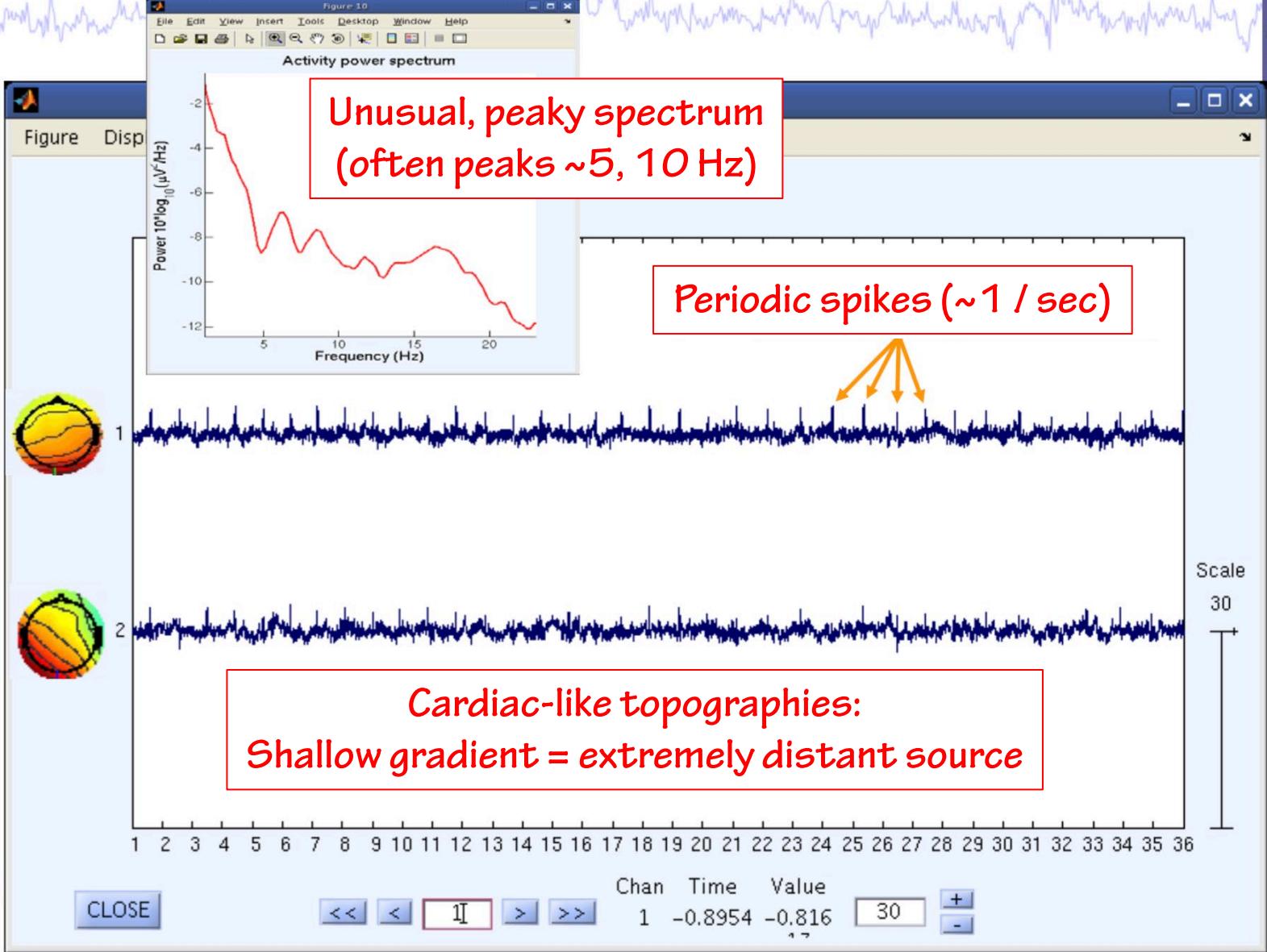
View components properties - pop\_viewprops() (dataset: faces\_4 epochs)



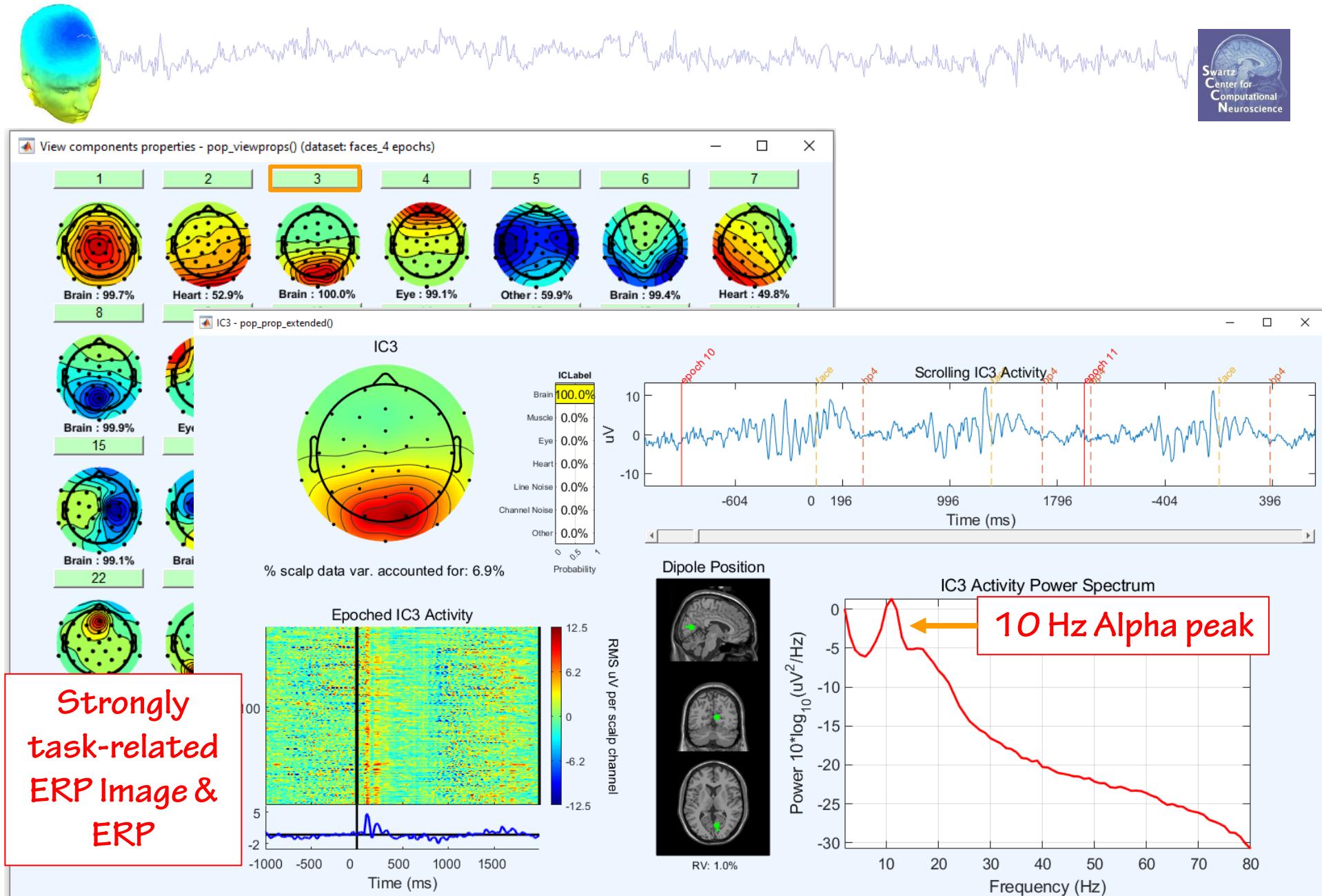
Deep dipole and periodic spikes



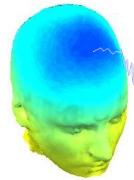
# ICs 2, 7 – Cardiac



# Brain ICs



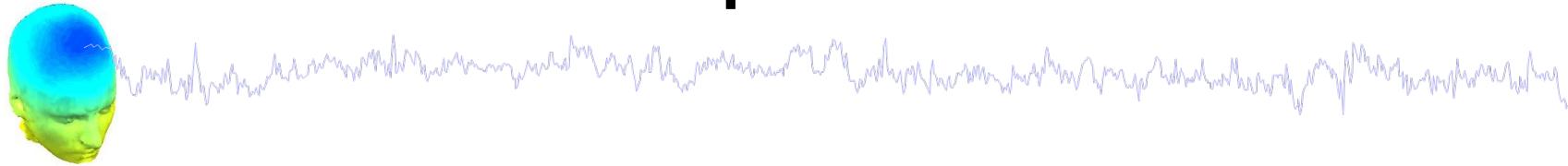
# Evaluating ICs



- 1. ICA introduction**
- 2. Run ICA**
- 3. IC evaluation**
- 4. Identify IC artifacts**
- 5. Plot IC activations**



# Component ERPs



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File Edit Tools Plot Study Datasets Help

#5: faces\_4 epochs faces

Channel locations

Channel data (scroll)

Channel spectra and maps

Channel properties

Channel ERP image

Channel ERPs

ERP map series

Sum/Compare ERPs

Component activations (scroll)

Component spectra and maps

Component maps

Component properties

Component ERP image

Component ERPs

Sum/Compare comp. ERPs

Data statistics

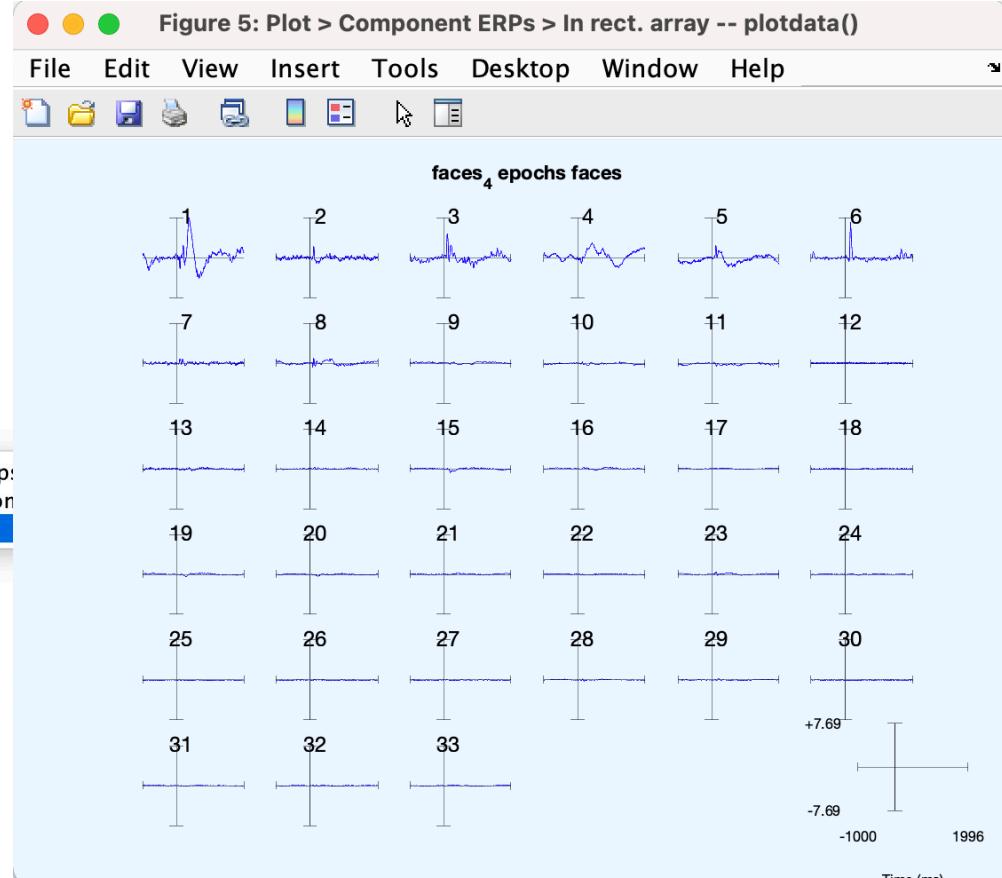
Time-frequency transforms

Component number(s): 1:33

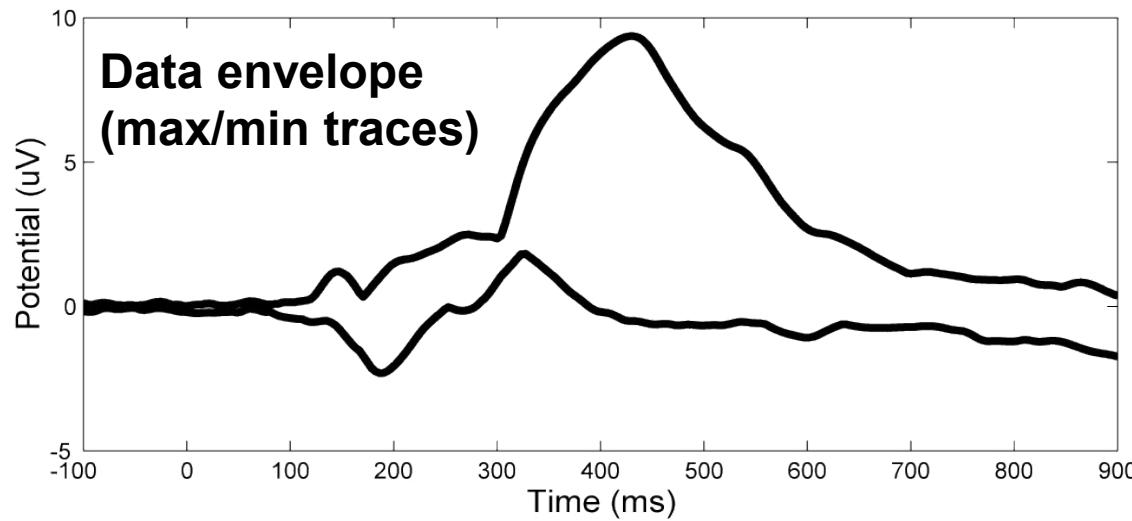
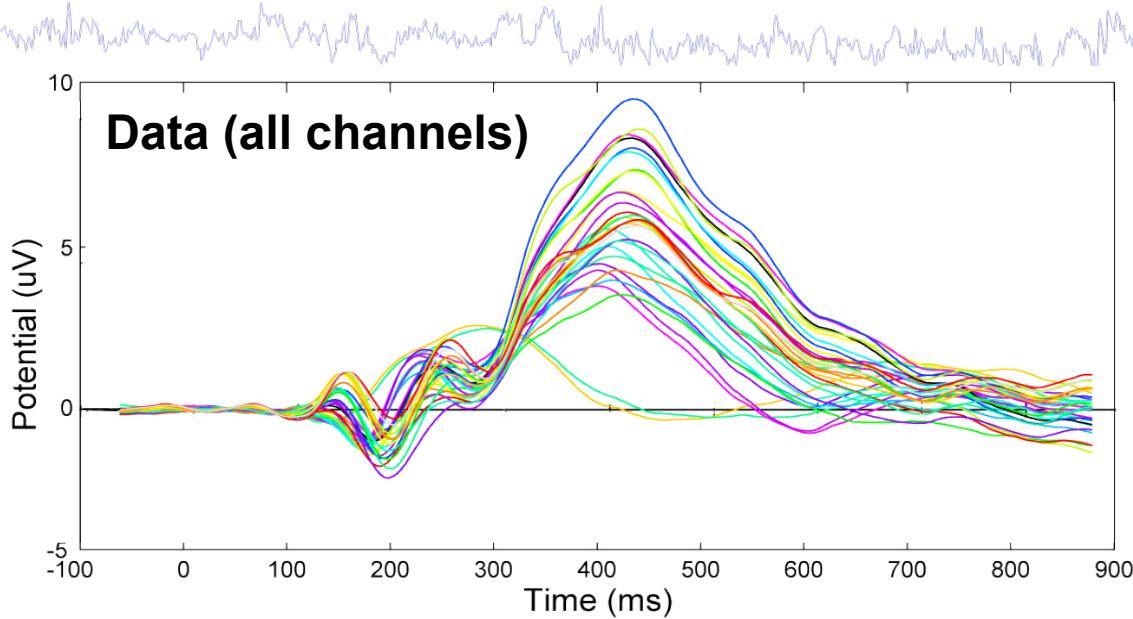
Plot title: faces\_4 epochs faces

Vertical limits ([0 0]-> data range): 0 0

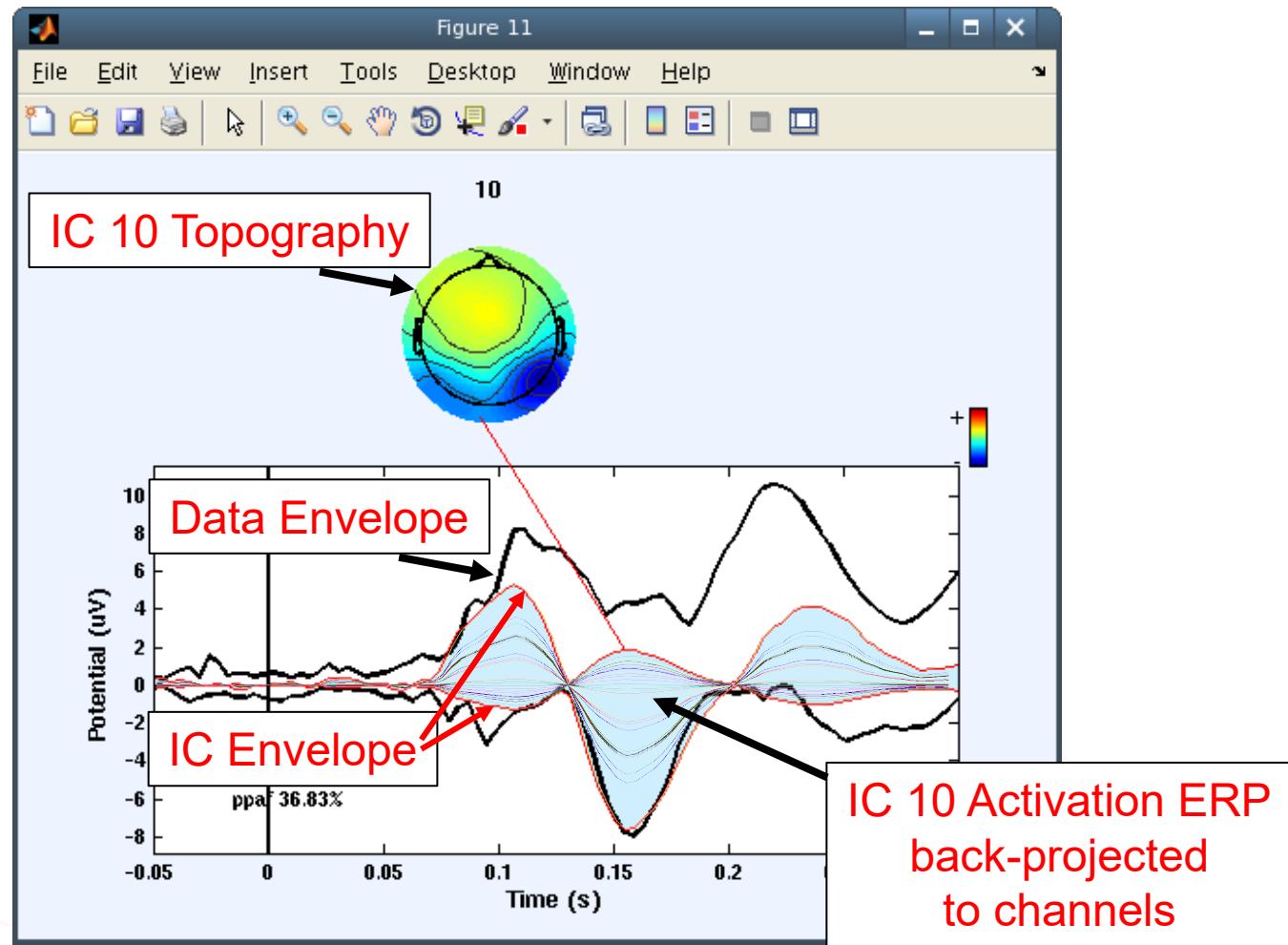
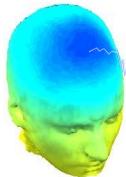
Help Cancel Ok



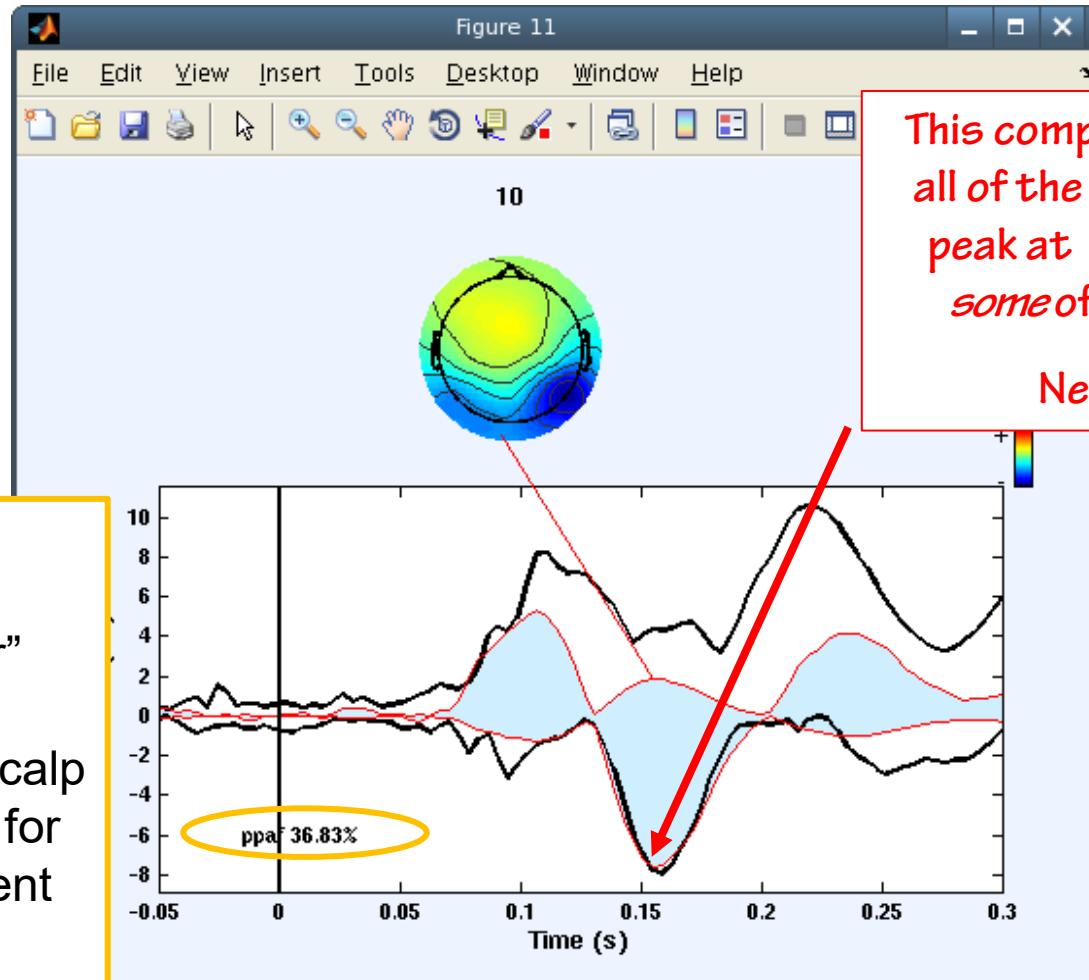
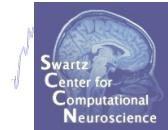
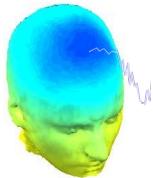
# Definition: The data envelope



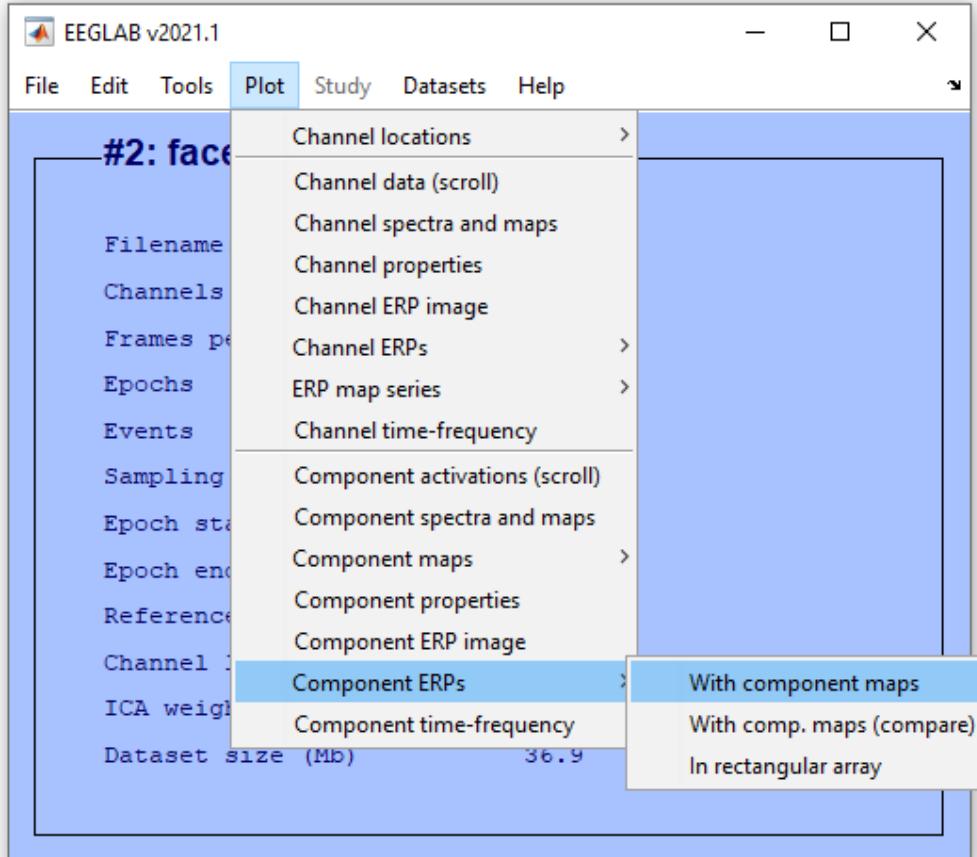
# Definition: IC Envelope



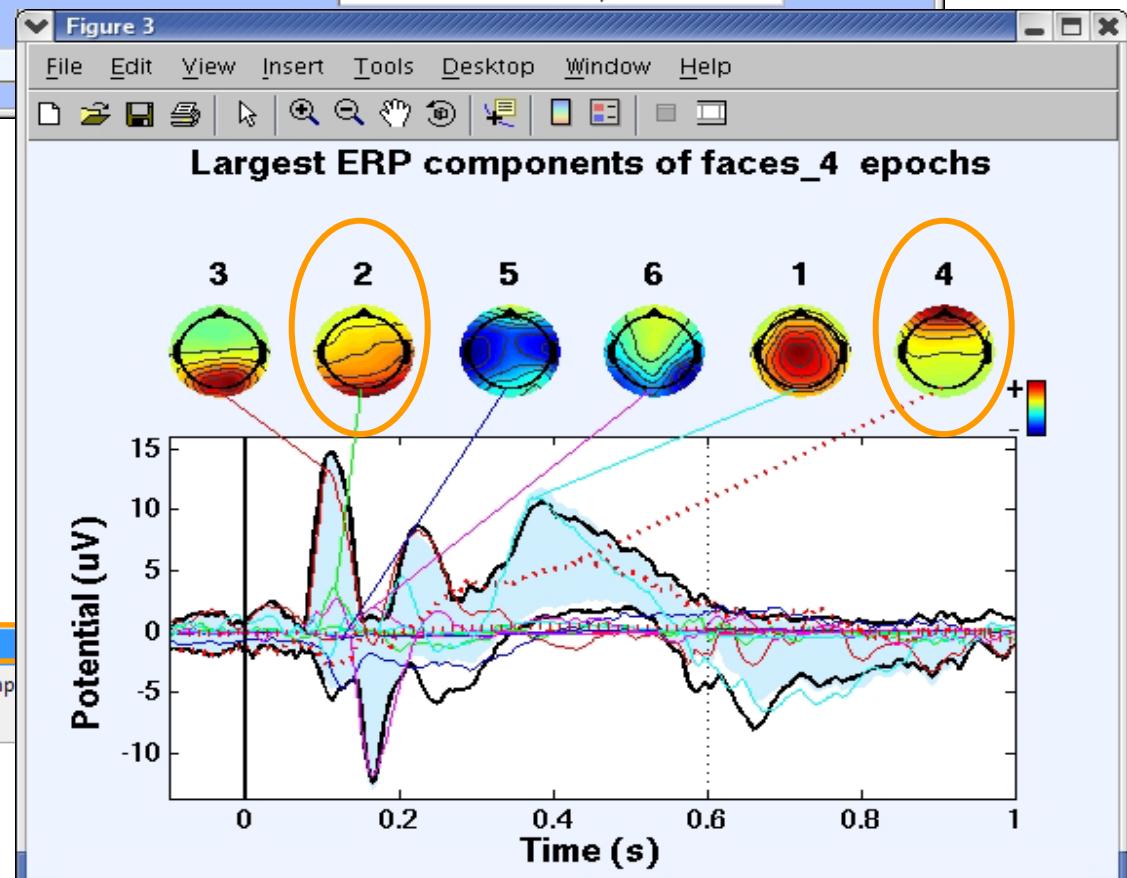
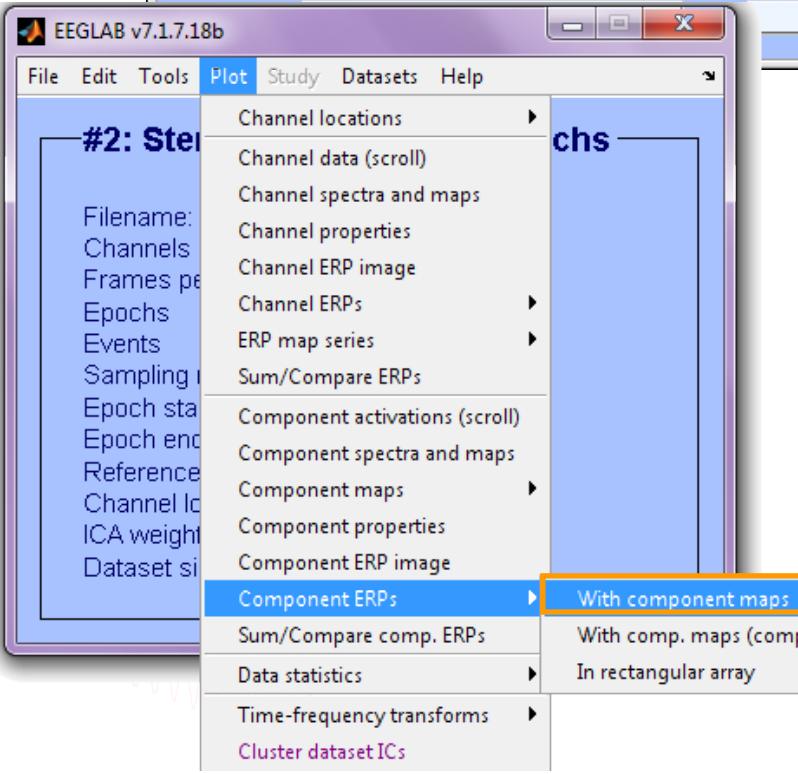
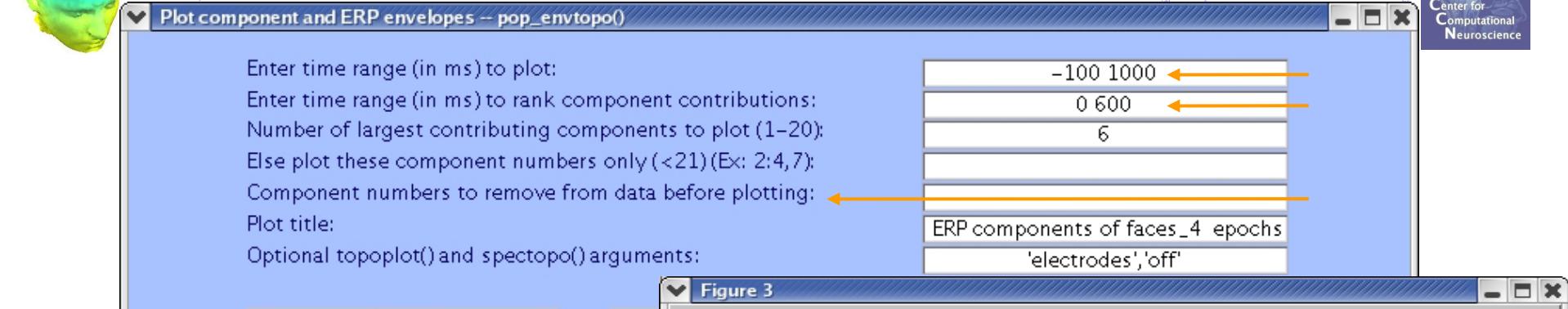
# Scalp ERP peaks are often the sum of multiple independent source processes



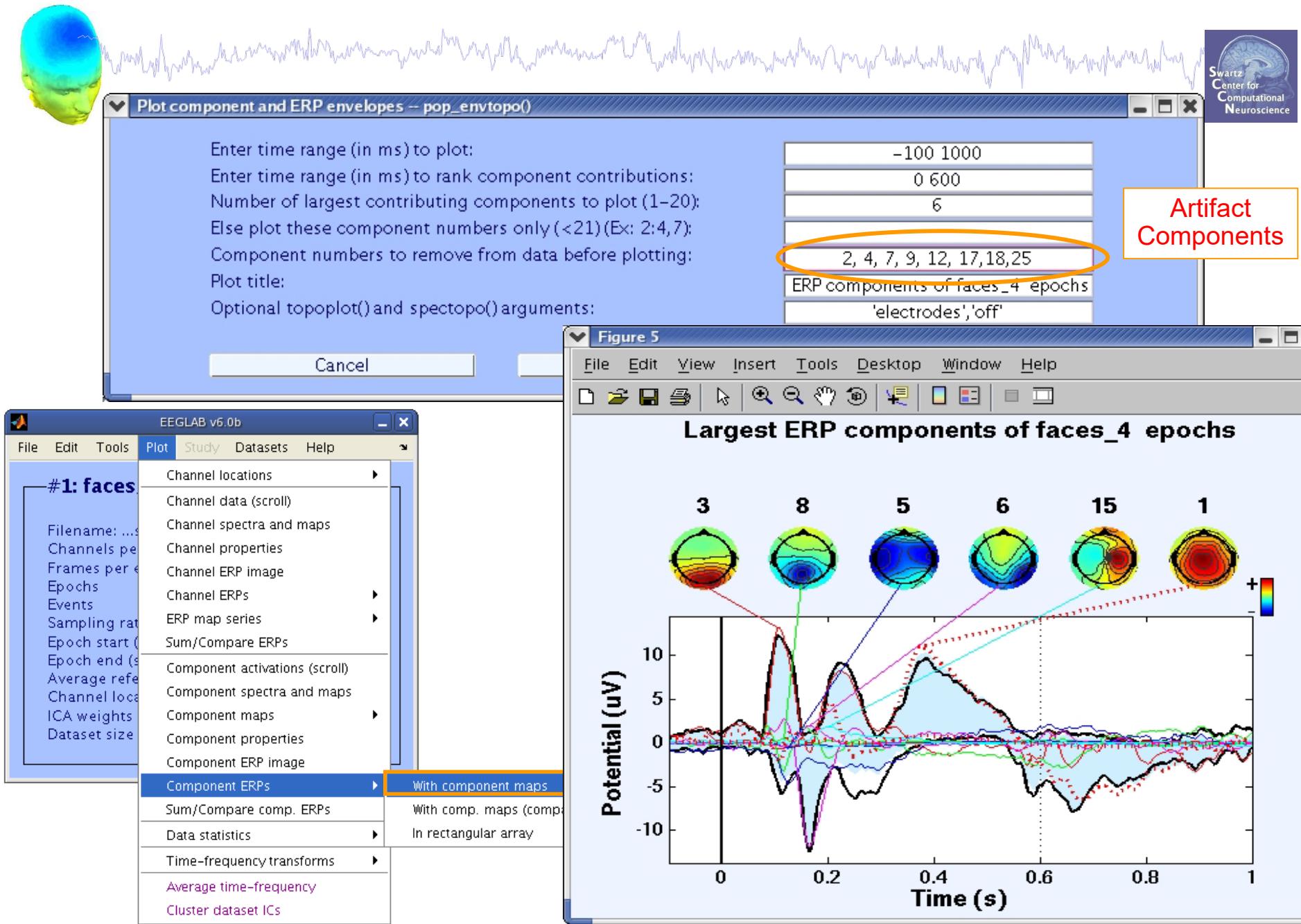
# Component ERP envelope



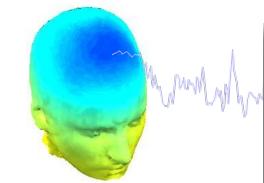
# IC contributions to ERP envelope



# Component contribution to the dataset ERP



# Plot component power



Component spectra and maps -- pop\_spectopo()

Epoch time range to analyze [min\_ms max\_ms]:  
Frequency (Hz) to analyze:  
Electrode number to analyze ([]=elec with max power; 0=whole scalp):  
Percent data to sample (1 to 100):  
Components to include in the analysis:  
Number of largest-contributing components to map:  
Else, map only these component numbers:  
[Checked] Compute comp spectra; [Unchecked] (data-comp) spectra:  
Plotting frequency range ([min max] Hz):  
Spectral and scalp map options (see topoplots):

0 2440526  
10 ←  
0  
20  
1:71  
5 ←  
  
2 25  
'electrodes','off'

Cancel Help

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#2: face

File Edit Tools Plot Study Datasets Help

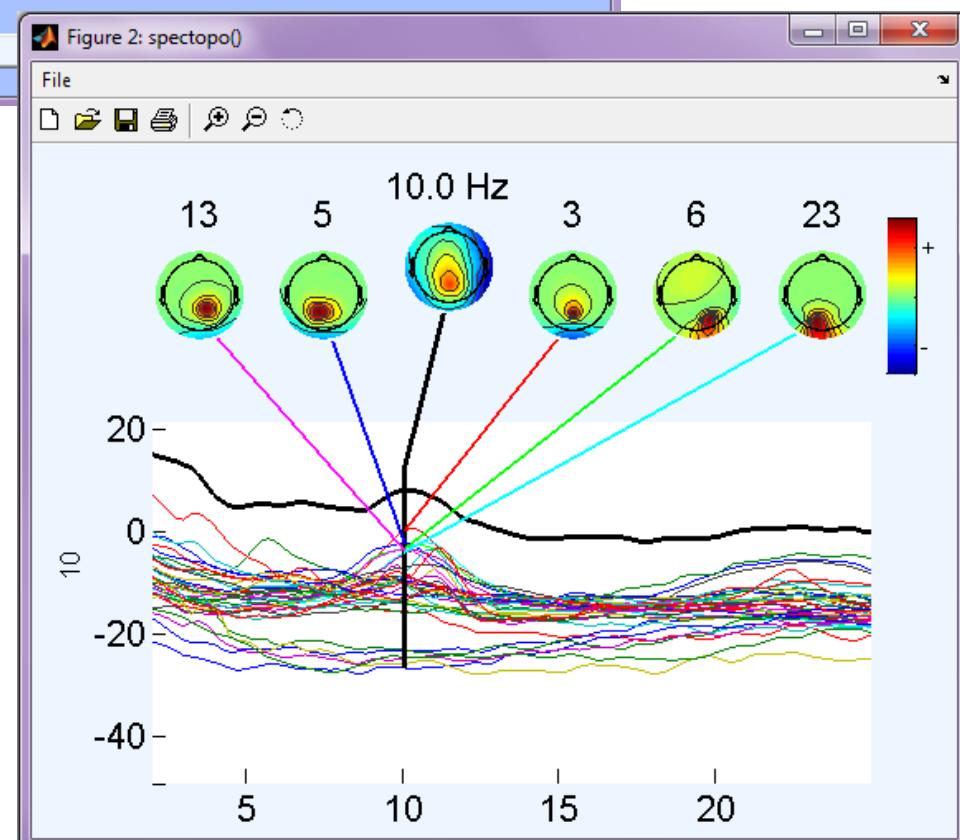
Channel locations >

Filename  
Channels  
Frames per second  
Epochs  
Events  
Sampling rate  
Epoch start time  
Epoch end time  
Reference  
Channel properties  
ICA weight matrix  
Dataset size (Mb)

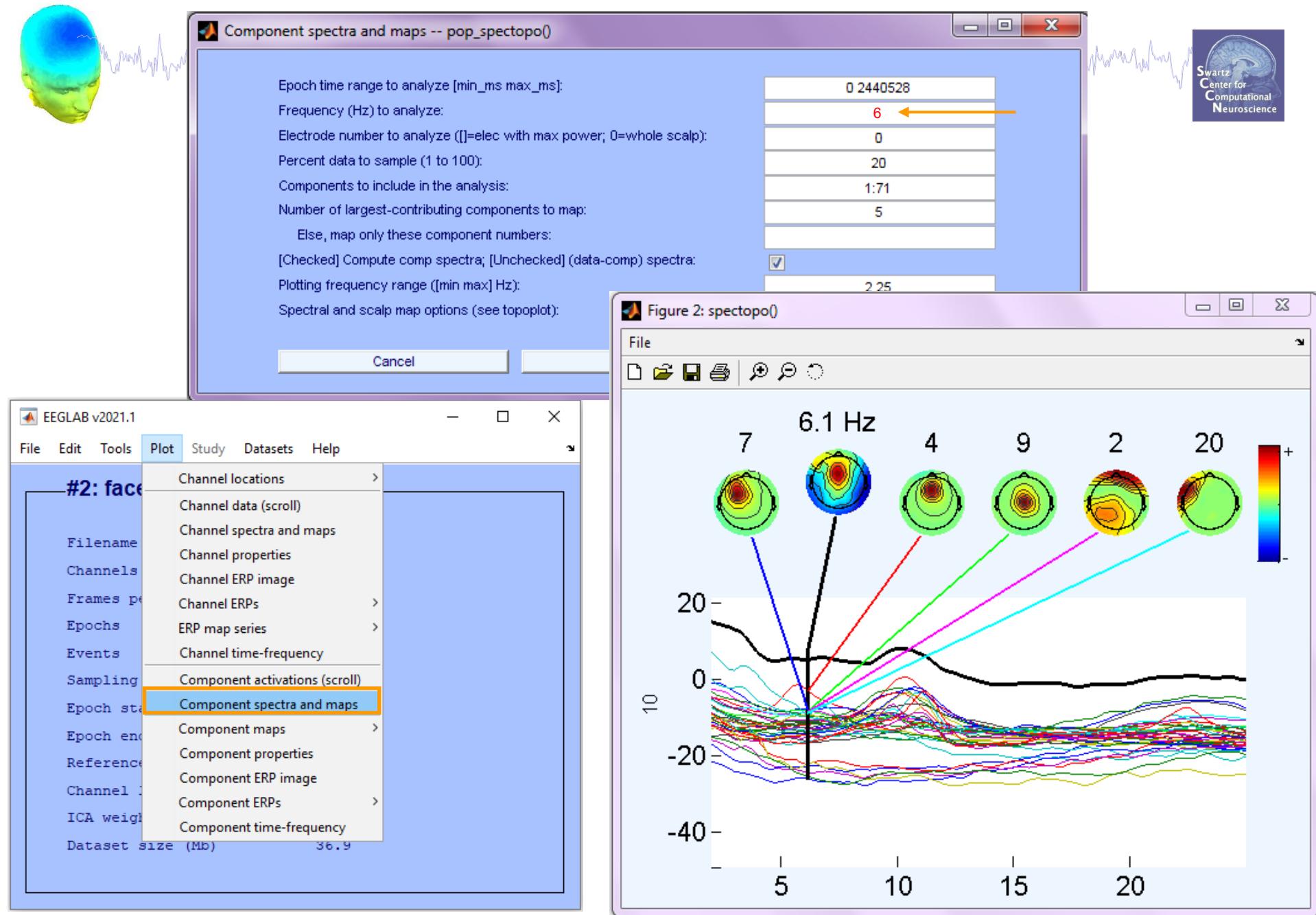
Component activations (scroll)  
**Component spectra and maps**

Component maps >  
Component properties  
Component ERP image  
Component ERPs >  
Component time-frequency

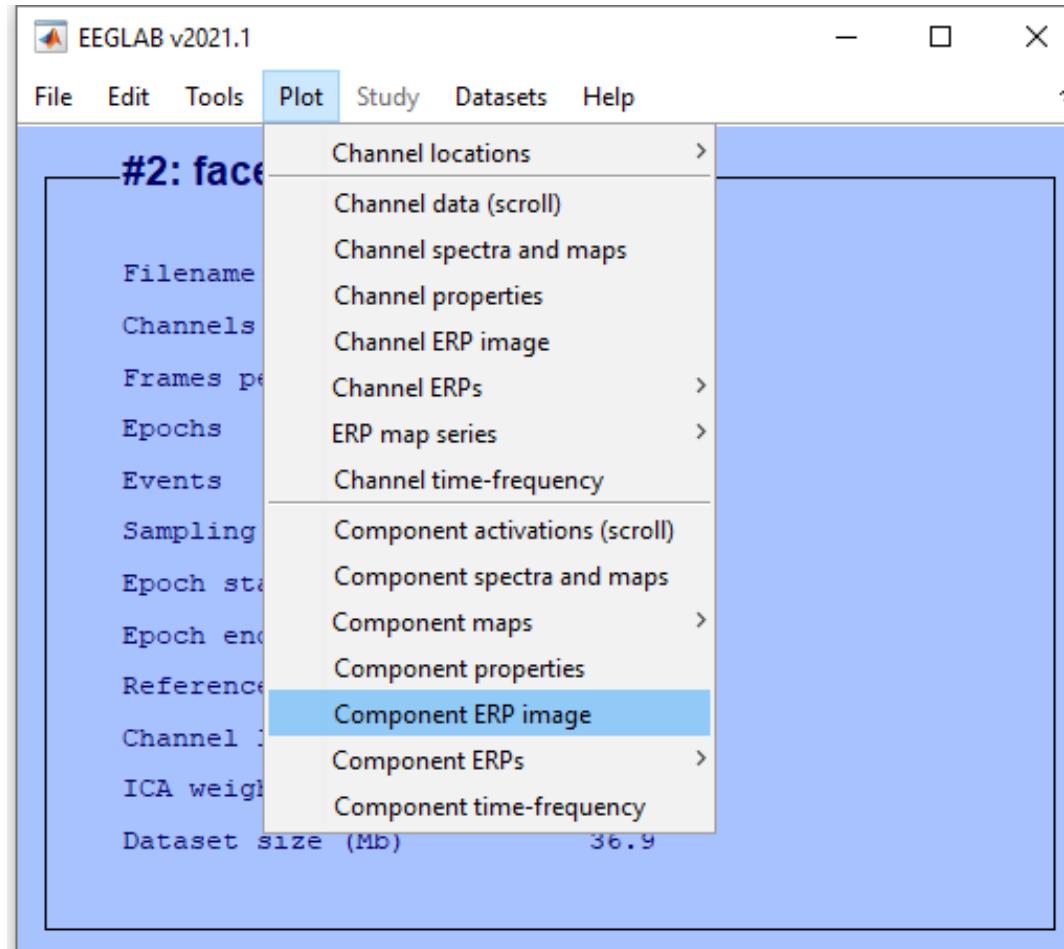
36.9



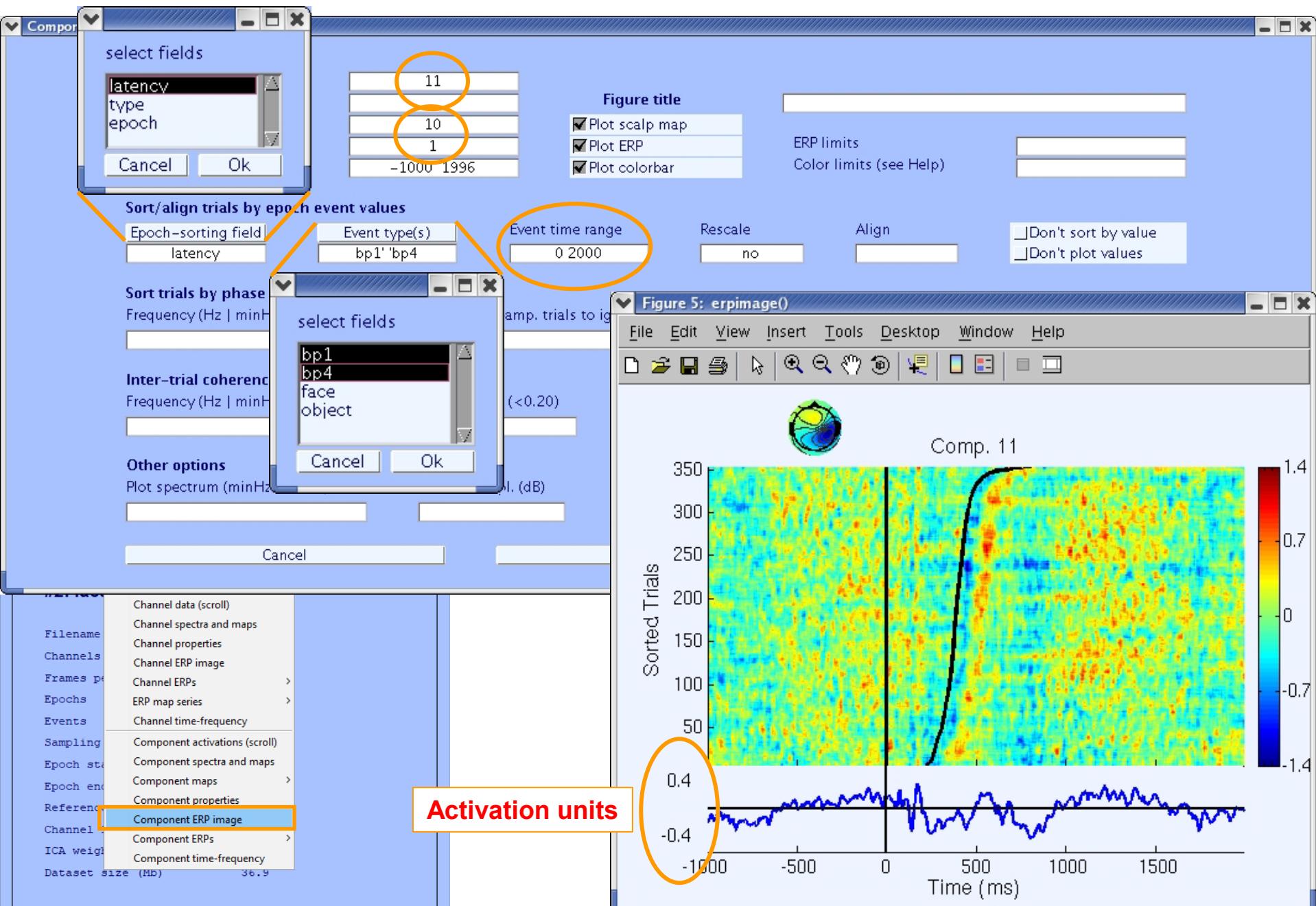
# Plot component power



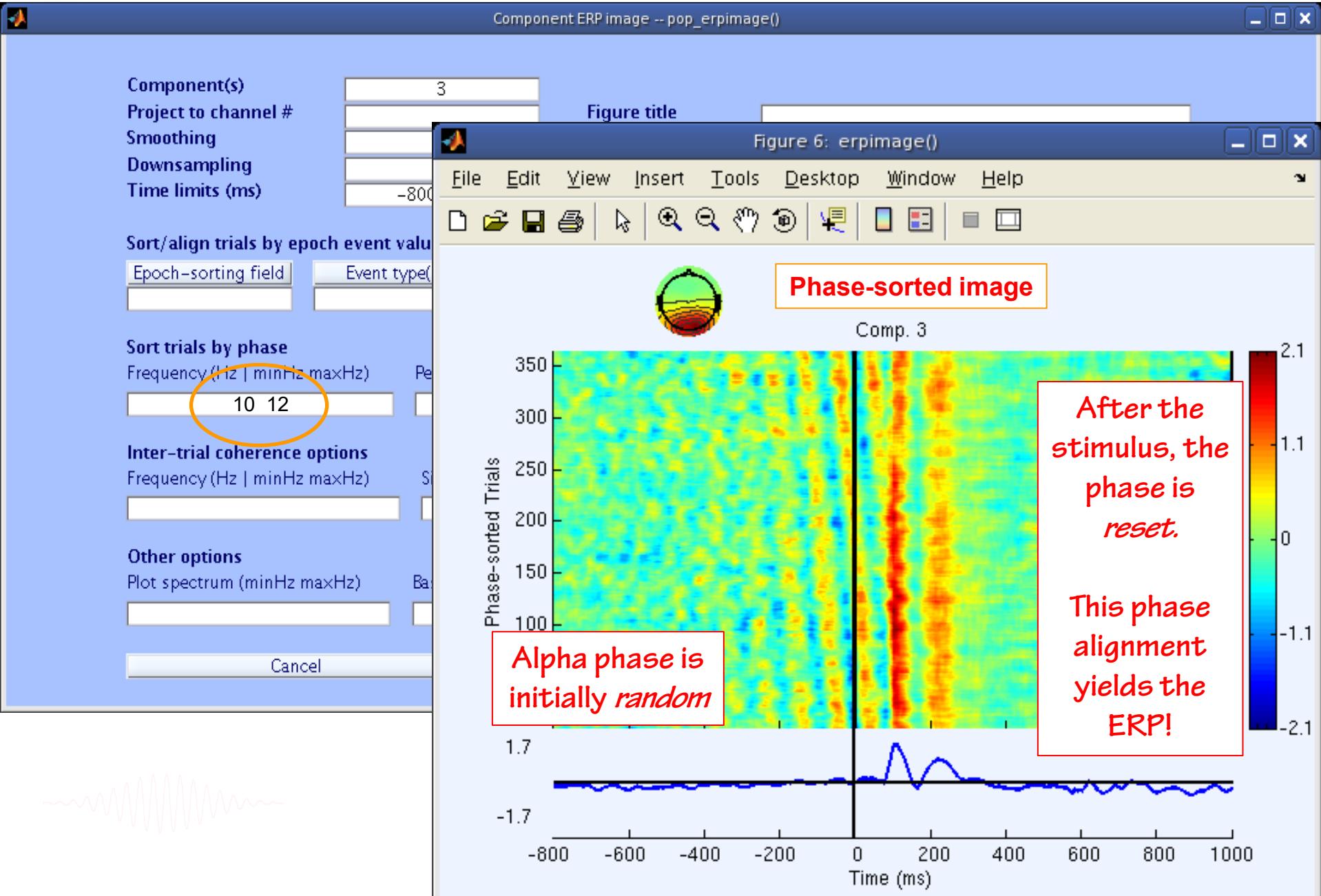
# Component ERP image



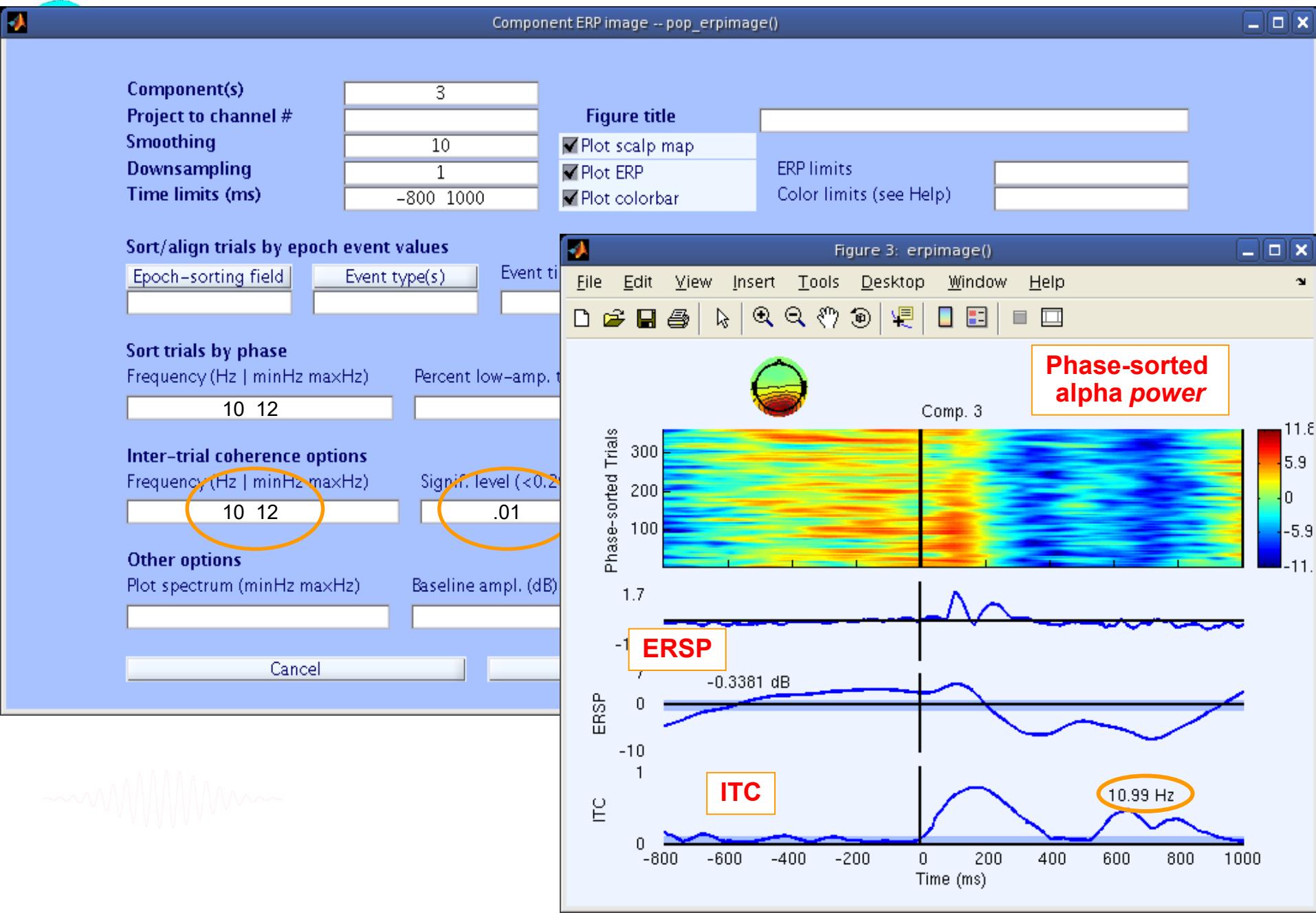
# Component ERP Images



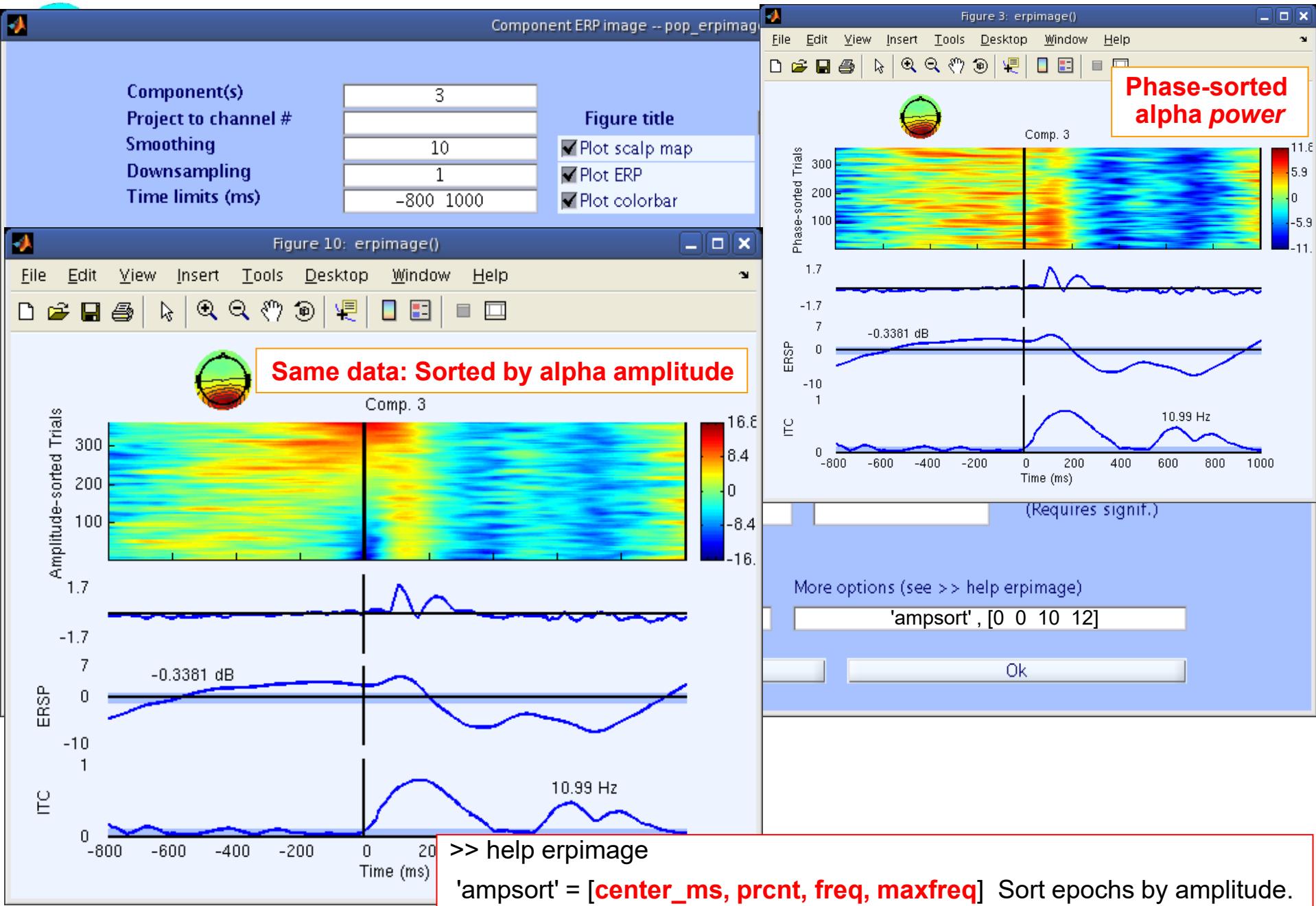
# Component ERP Images: Sort by phase



# Component ERP Images: ITC



# Component ERP Images: Sort by amplitude



# Component ERP Images: Amplitude vs. Activations

