

# Artifact rejection and running ICA



## Task 1

Reject noisy data

## Task 2

Run ICA

## Task 3

Plot components

## Task 4

Remove components  
(i.e. back-projection)

## Exercise...



# Artifact rejection and running ICA



## Task 1

Reject noisy data

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Plot components

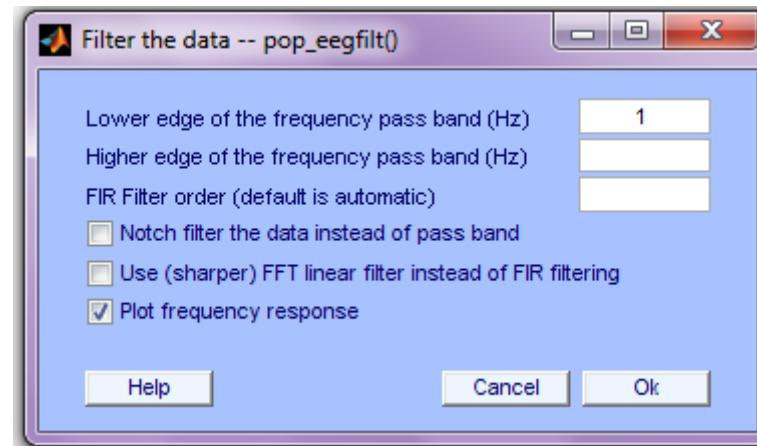
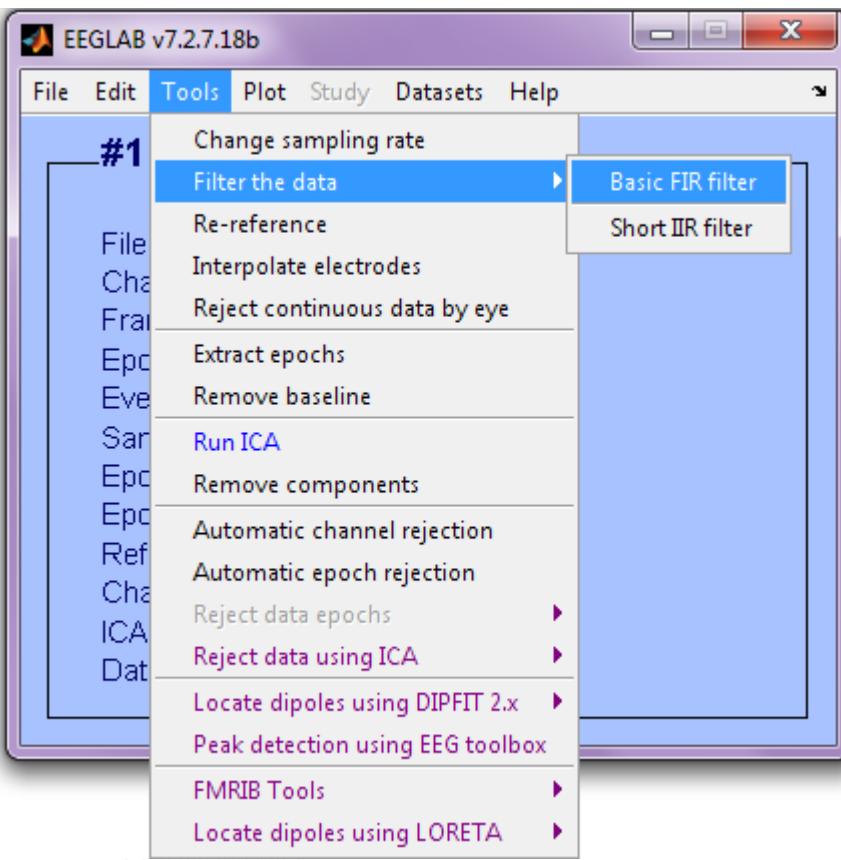
## Task 4

Remove components  
(i.e. back-projection)

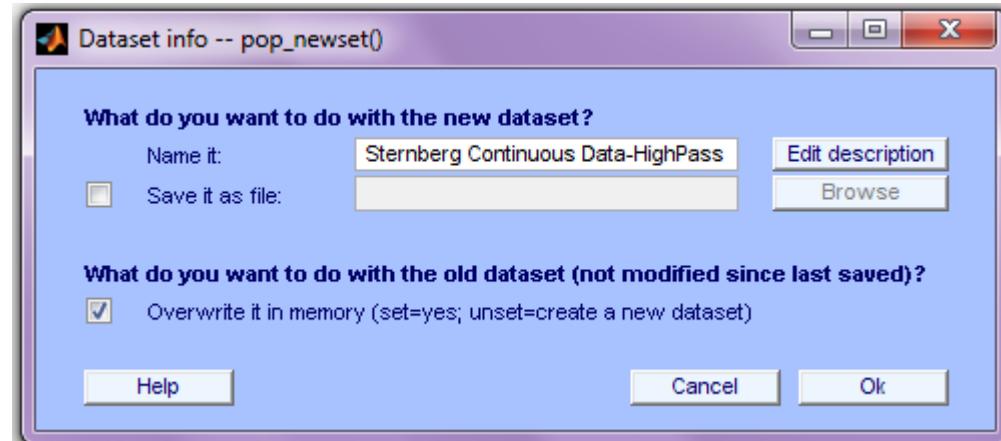
## Exercise...



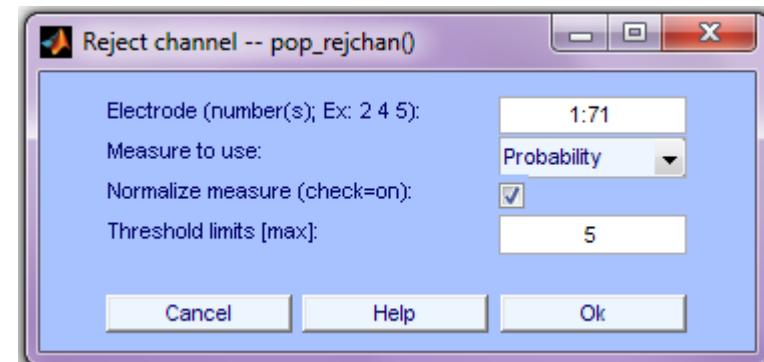
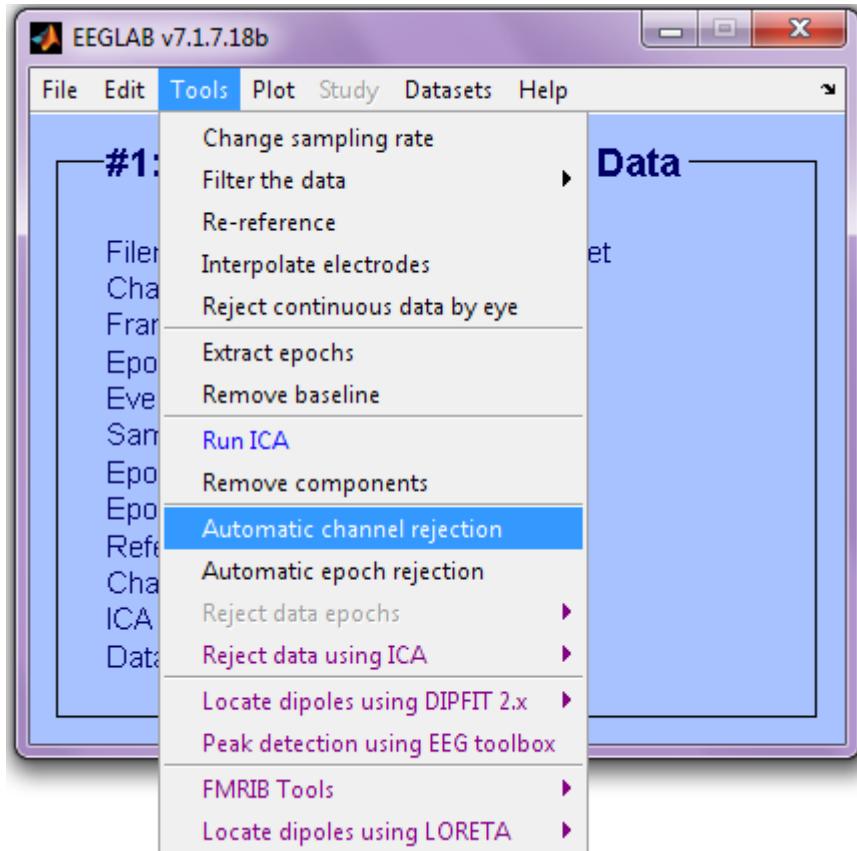
# Filter the data (if necessary/desired)



High-pass

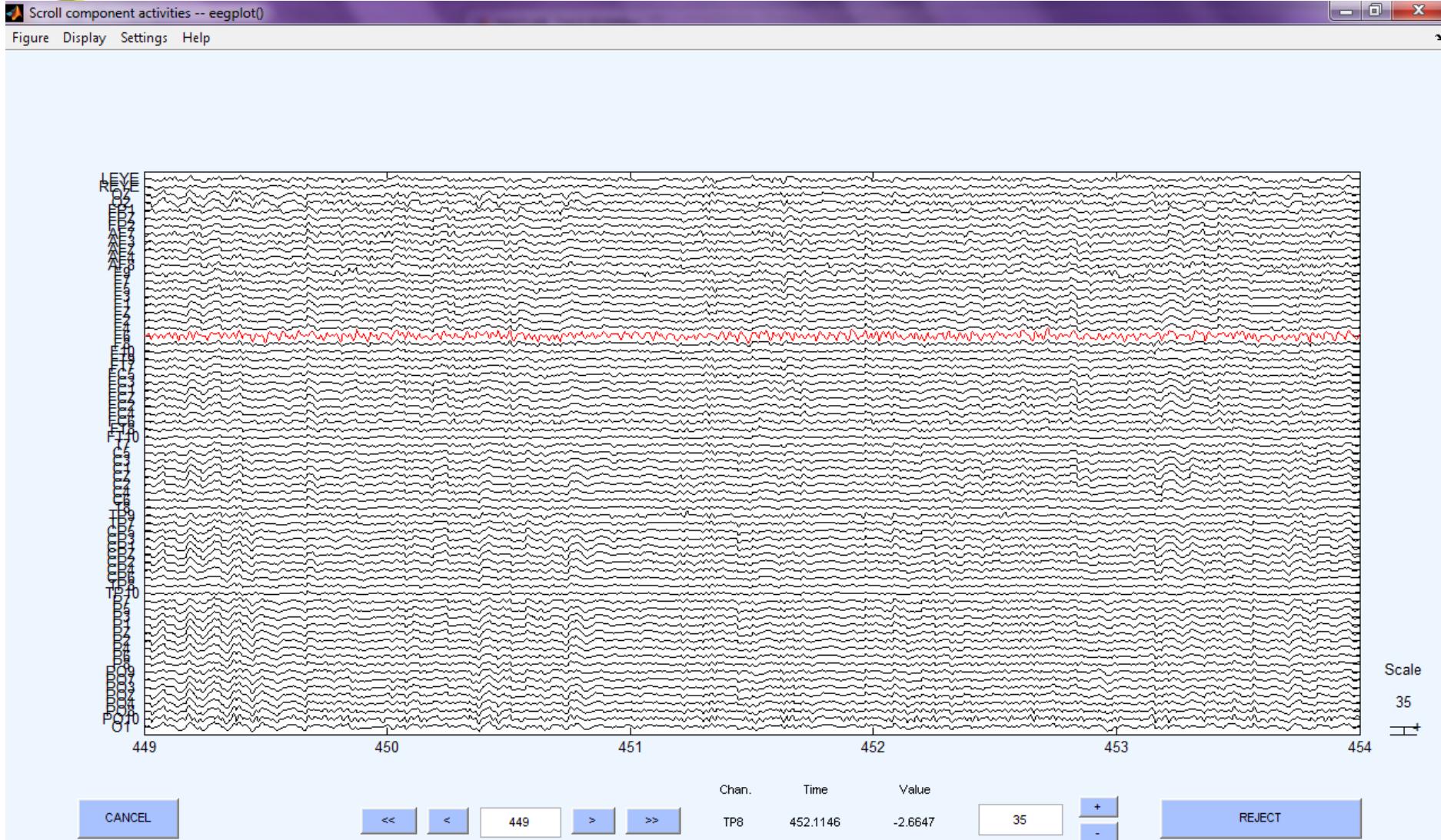
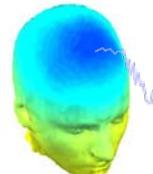


# Auto-detection of noisy channels



```
>> EEG = pop_rejchan(EEG, 'elec',[1:71] , 'threshold',5,...  
'norm', 'on', 'measure', 'prob');
```

# Auto-detected noisy channel



# Reject continuous data

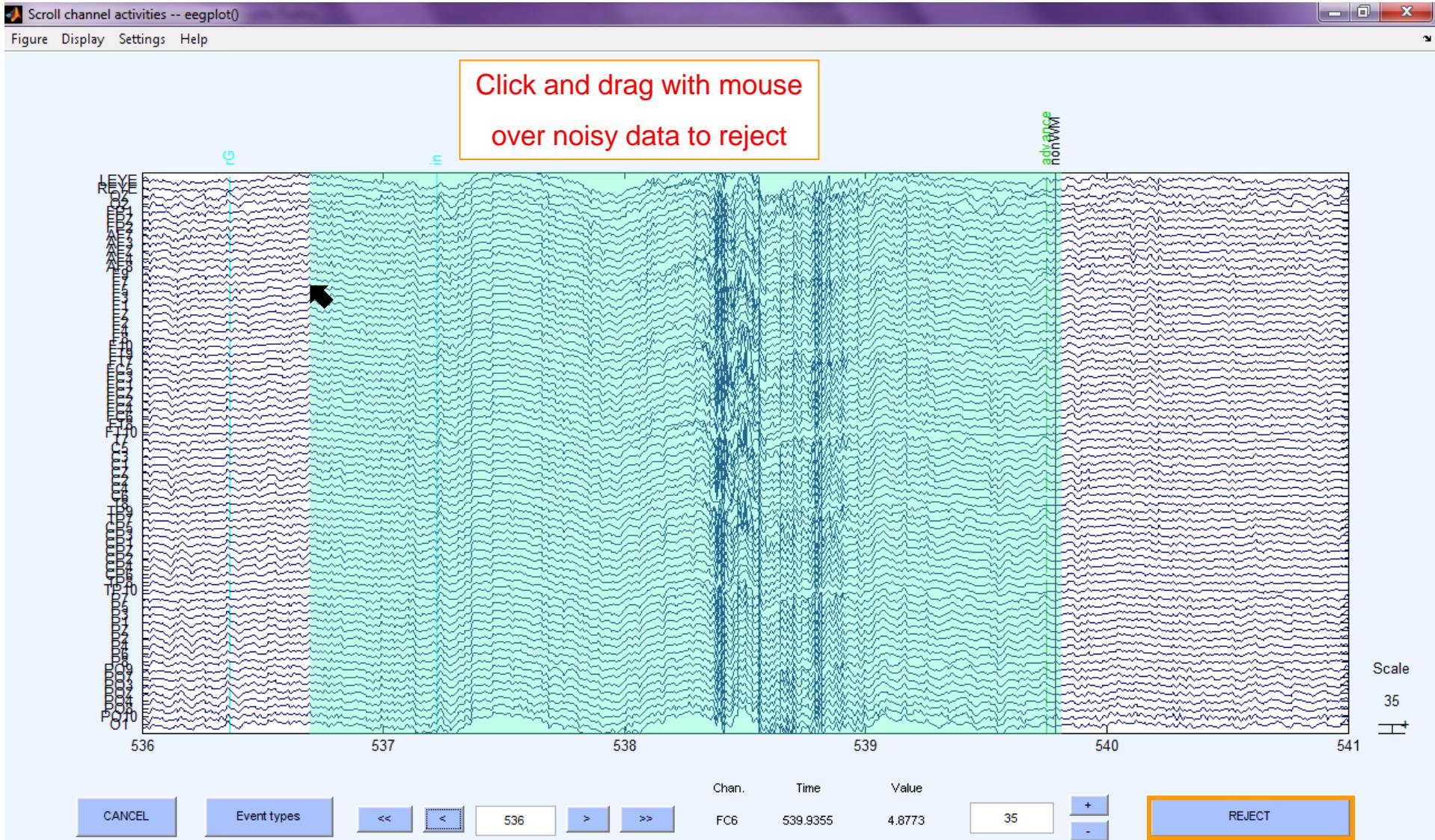


Equivalent

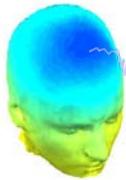
The image shows three windows from the EEGLAB software:

- EEGLAB v7.1.7.18b (Top Left):** A main window with a menu bar (File, Edit, Tools, Plot, Study, Datasets, Help). The "Tools" menu is open, showing various options like "Change sampling rate", "Filter the data", and "Reject continuous data by eye". The "Reject continuous data by eye" option is highlighted with a blue box.
- EEGLAB v7.1.7.18b (Top Right):** Another main window with the same menu bar. The "Plot" menu is open, showing options like "Channel locations", "Channel data (scroll)" (which is highlighted with a yellow box), and "Channel spectra and maps".
- Warning Dialog (Bottom):** A small window titled "Warning" containing instructions: "Mark stretches of continuous data for rejection by dragging the left mouse button. Click on marked stretches to unmark. When done, press 'REJECT' to excise marked stretches (Note: Leaves rejection boundary markers in the event table)". It has "Cancel" and "Continue" buttons at the bottom.

# Reject continuous data



# Rejecting data for ICA



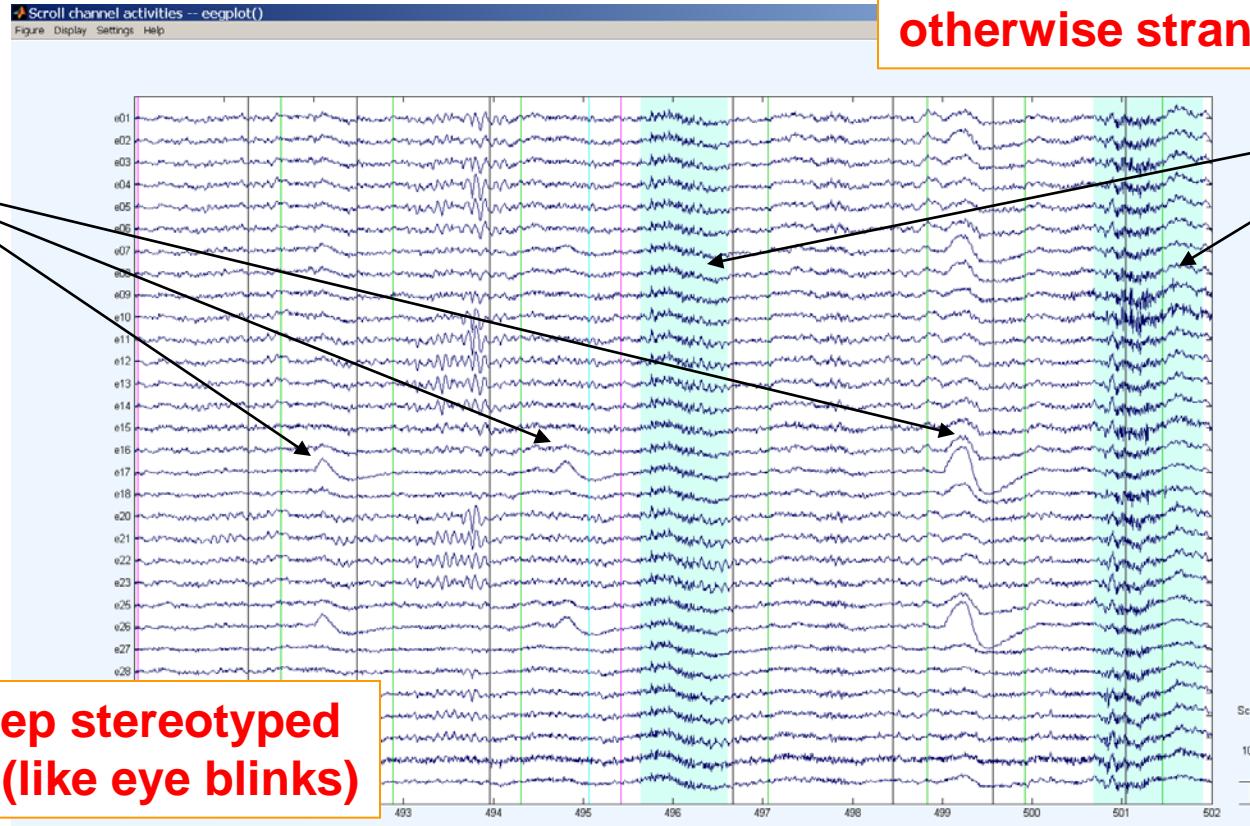
To prepare data for ICA:

Reject large muscle or otherwise strange events...

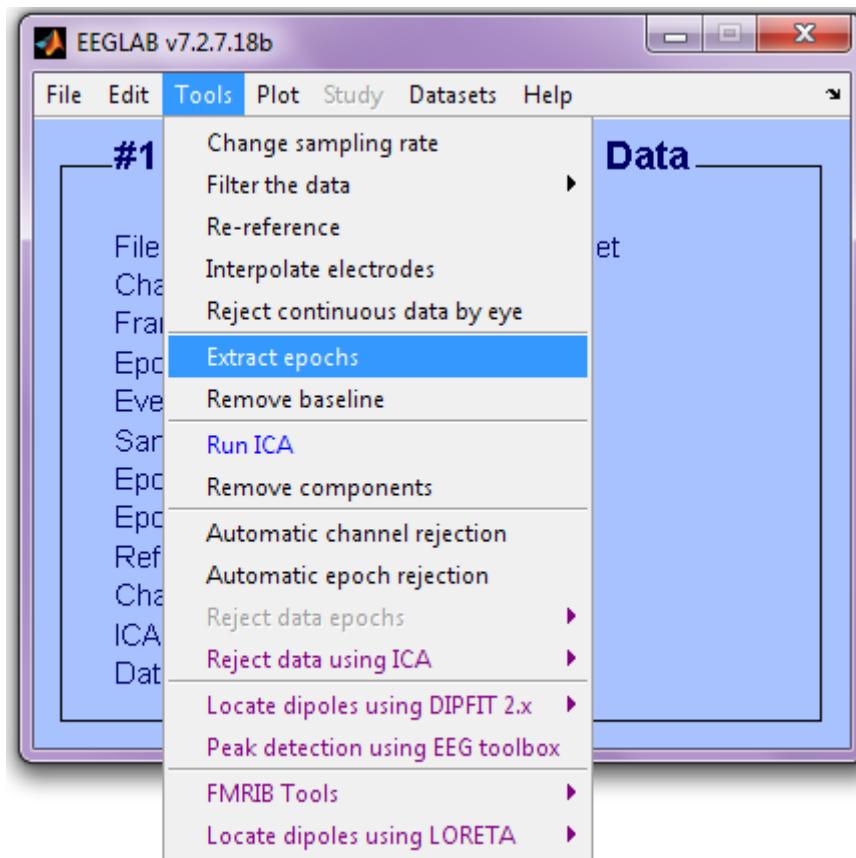
Keep

Reject

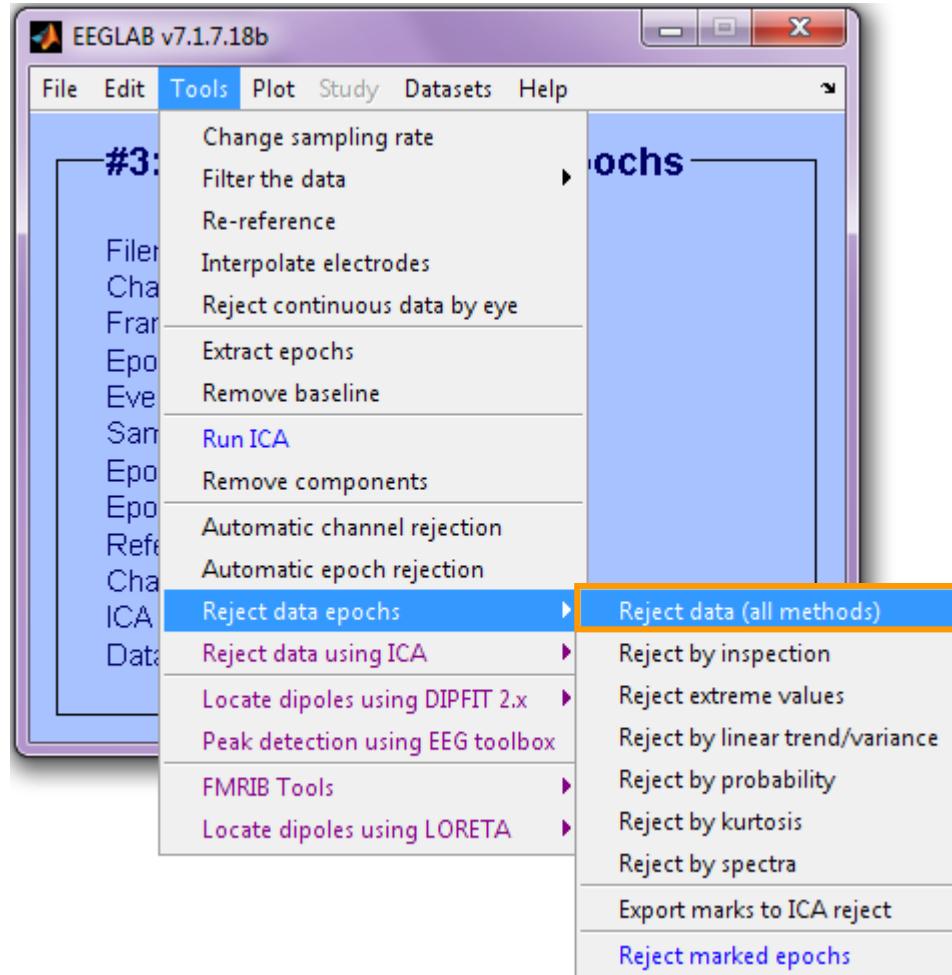
... but keep stereotyped artifacts (like eye blinks)



# OR... Extract short epochs



# Auto-reject data epochs



# Reject data epochs



visual  
inspection

Reject trials using data statistics - pop\_rejmenu()

**Mark trials by appearance**

**Find abnormal values**  
Upper limit(s) (uV)   
Start time(s) (ms)   
Electrode(s)

Scroll Data      Marked trials 0

Lower limit(s) (uV)   
Ending time(s) (ms)   
Currently marked trials 0

**Find abnormal trends**  
Max slope (uV/epoch)   
Electrode(s)

R-squared limit (0 to 1)   
Currently marked trials 0

**Find improbable data**  
Single-channel limit (std. dev.)   
Electrode(s)

All channels limit (std. dev.)   
Currently marked trials 0

**Find abnormal distributions**  
Single-channel limit (std. dev.)   
Electrode(s)

All channels limit (std. dev.)   
Currently marked trials 0

**Find abnormal spectra (slow)**  
Upper limit(s) (dB)   
Low frequency(s) (Hz)   
Electrode(s)

Lower limit(s) (dB)   
High frequency(s) (Hz)   
Currently marked trials 0

**Plotting options**

Show all trials marked for rejection by the measure selected above or checked below

Abnormal appearance     Abnormal values     Abnormal trends  
 Improbable epochs     Abnormal distributions     Abnormal spectra



probability

# Reject data epochs



Start by clicking Calculate:

Number of epochs above threshold indicated here

Reject trials using data statistics - pop\_rejmenu()

**Mark trials by appearance**

**Find abnormal values**

Upper limit(s) (uV): 25  
Start time(s) (ms): -500  
Electrode(s): 1:70

Lower limit(s) (uV): -25  
Ending time(s) (ms): 496  
Currently marked trials: 0

**Find abnormal trends**

Max slope (uV/epoch): 50  
Electrode(s): 1:70

R-squared limit (0 to 1): 0.3  
Currently marked trials: 0

**Find improbable data**

Single-channel limit (std. dev.): 5  
Electrode(s): 1:70

All channels limit (std. dev.): 5  
Currently marked trials: 32

**Find abnormal distributions**

Single-channel limit (std. dev.): 5  
Electrode(s): 1:70

All channels limit (std. dev.): 5  
Currently marked trials: 0

**Find abnormal spectra (slow)**

Upper limit(s) (dB): 25  
Low frequency(s) (Hz): 0  
Electrode(s): 1:70

Lower limit(s) (dB): -25  
High frequency(s) (Hz): 50  
Currently marked trials: 0

**Plotting options**

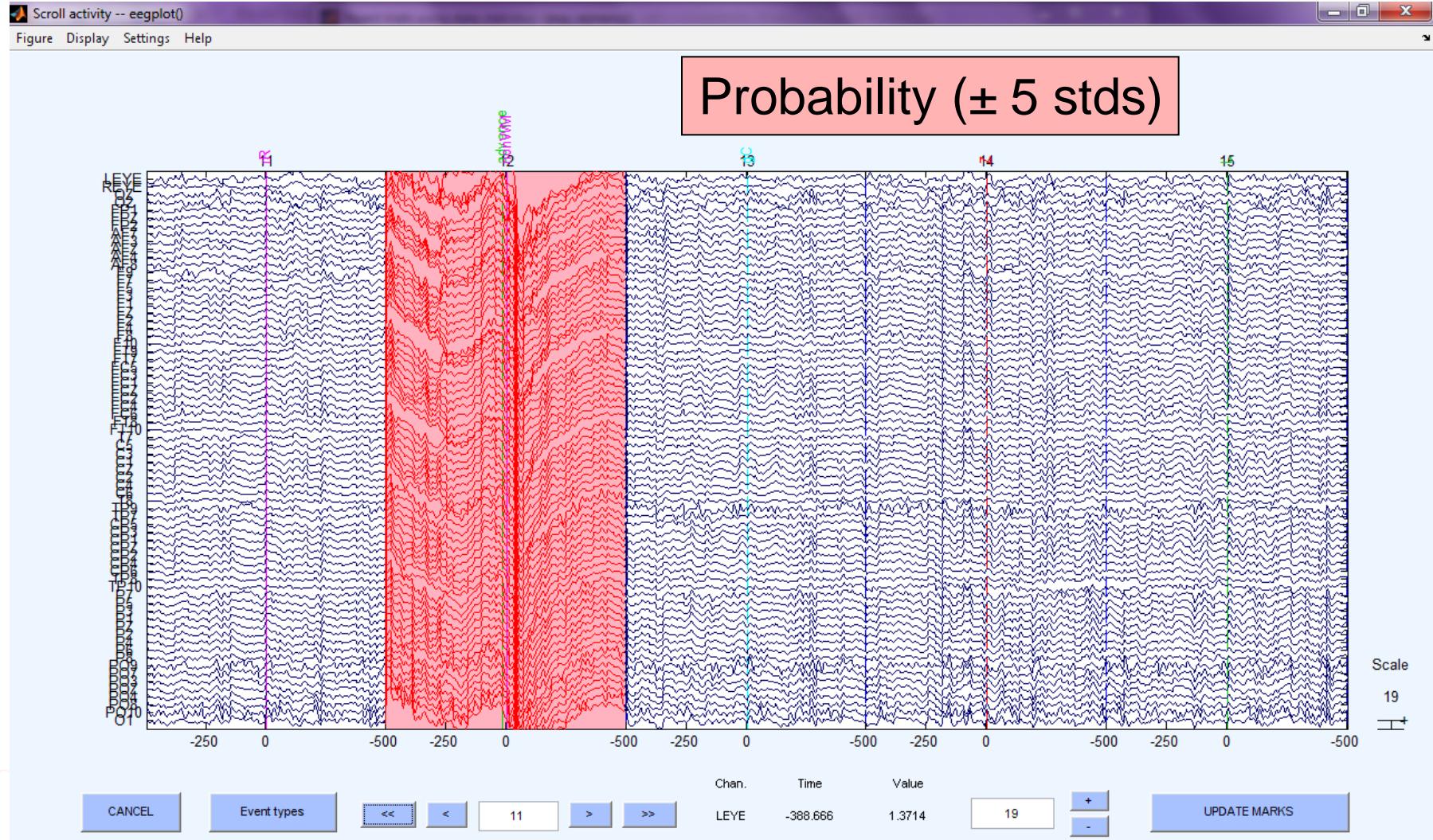
Show all trials marked for rejection by the measure selected above or checked below

Abnormal appearance    Abnormal values    Abnormal trends  
 Improbable epochs    Abnormal distributions    Abnormal spectra

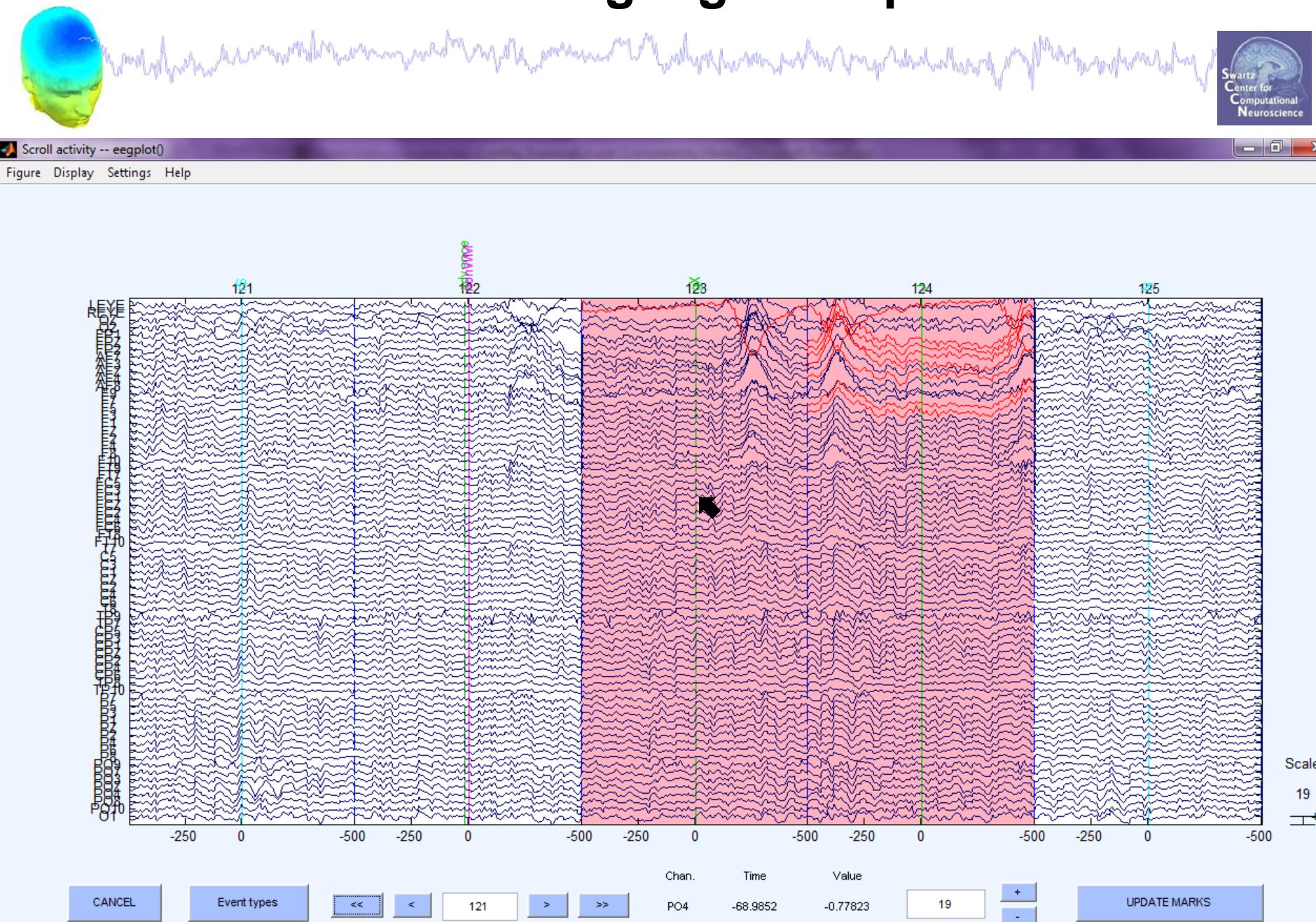
**Buttons**

Close (keep marks)   Clear all marks   Reject marked trials

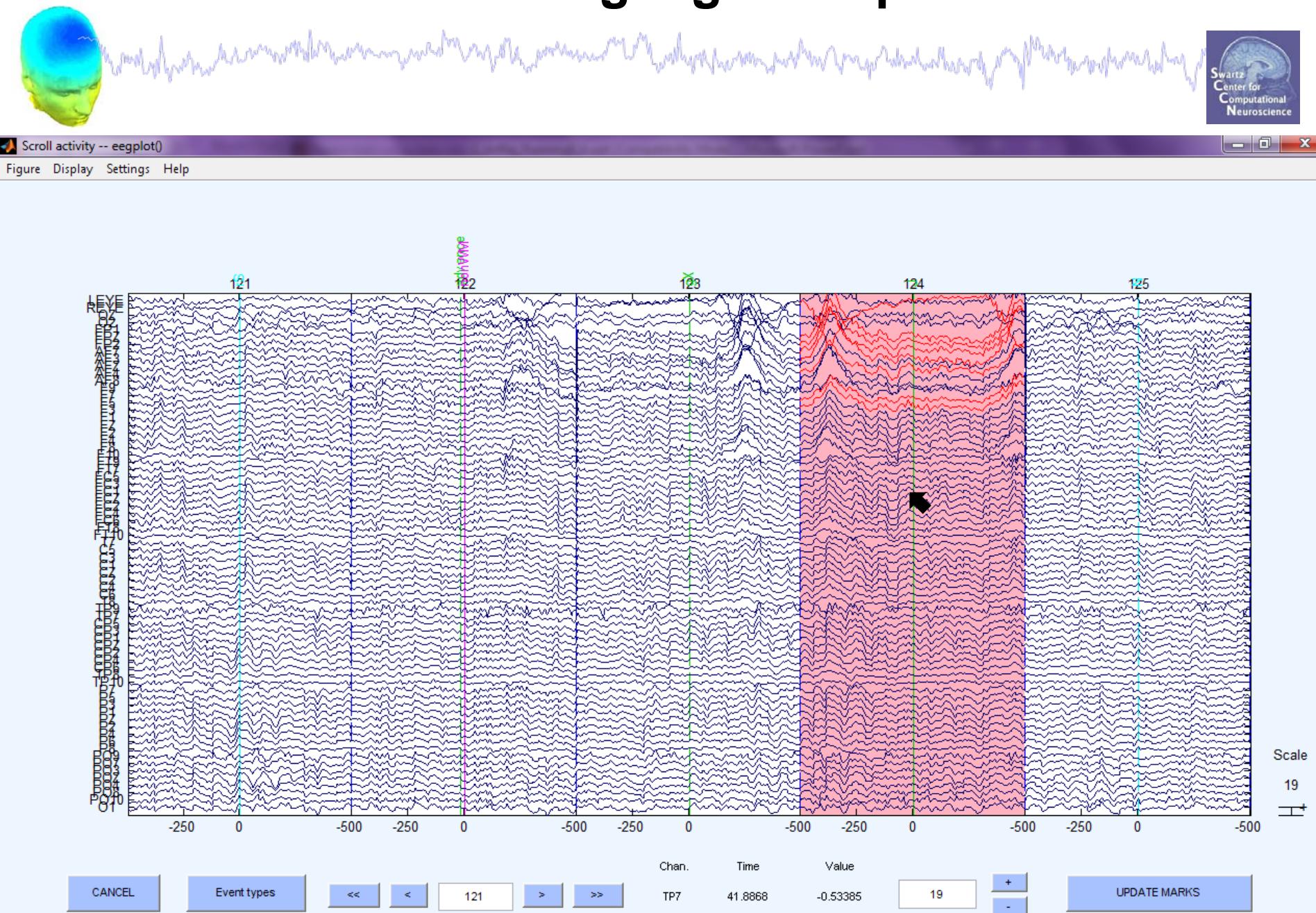
# Reject data epochs

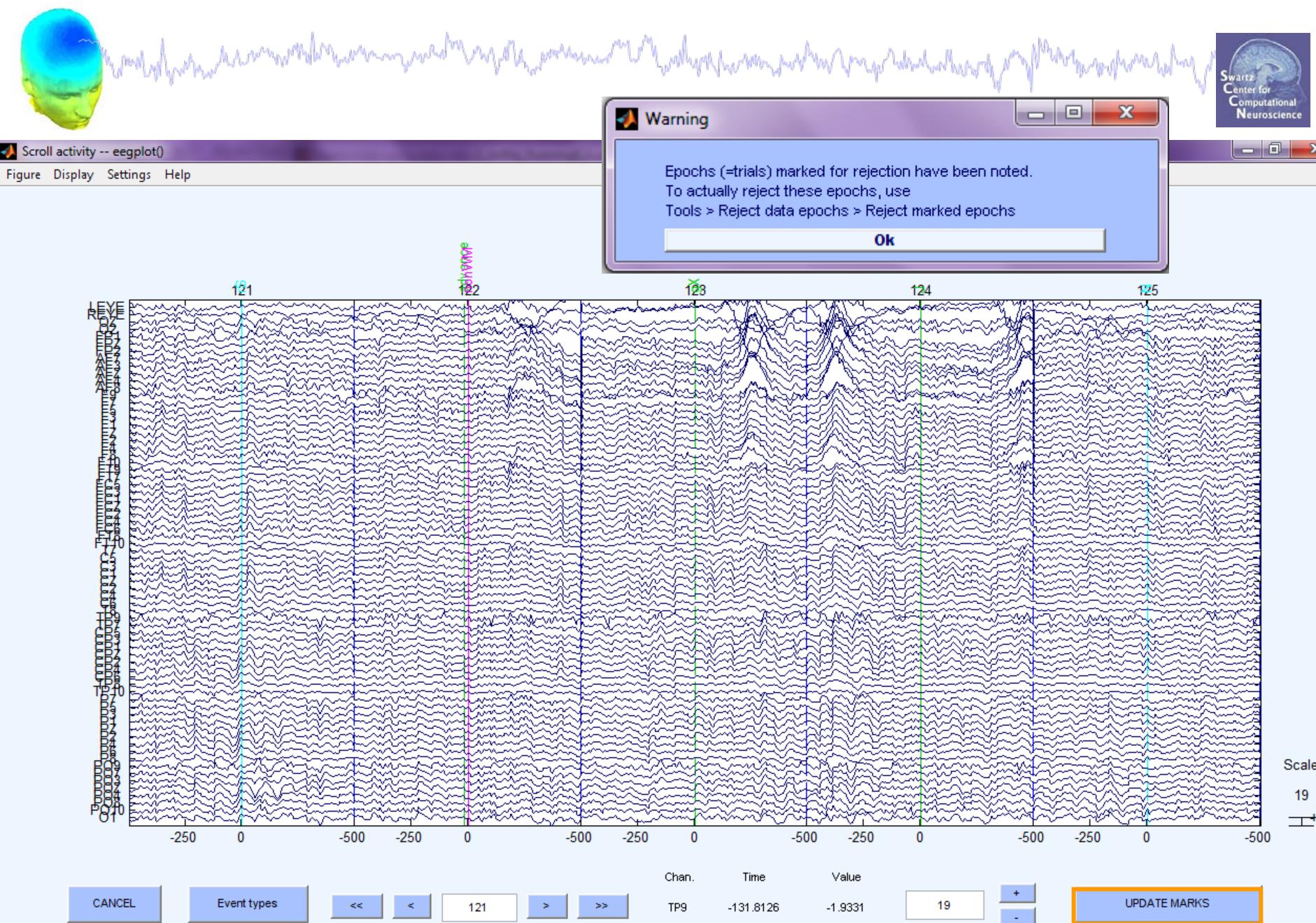


# Un-select highlighted epochs



# Un-select highlighted epochs





# Plot channel measures over time



Reject trials using data statistics - pop\_rejmenu()

**Mark trials by appearance**

**Find abnormal values**

Upper limit(s) (uV)	25
Start time(s) (ms)	-1000
Electrode(s)	1:31

**Find abnormal trends**

Max slope (uV/epoch)	50
Electrode(s)	1:31

**Find improbable data**

Single-channel limit (std. dev.)	5
Electrode(s)	1:31

**Find abnormal distributions**

Single-channel limit (std. dev.)	5
Electrode(s)	1:31

**Find abnormal spectra (slow)**

Upper limit(s) (dB)	25
Low frequency(s) (Hz)	0
Electrode(s)	1:31

**Plotting options**

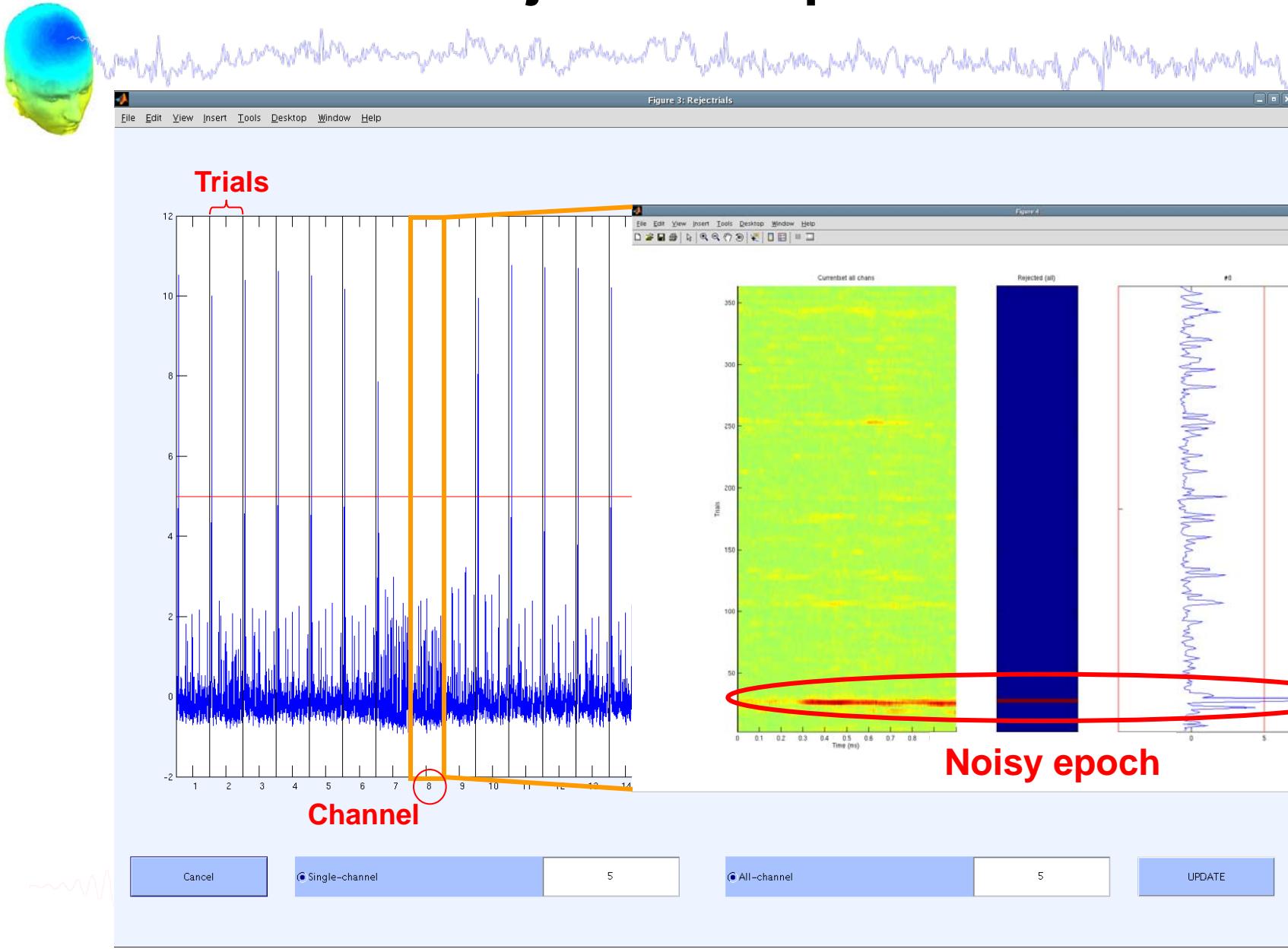
Show all trials marked for rejection by the measure selected above or checked below

Abnormal appearance     Abnormal values     Abnormal trends  
 Improbable epochs     Abnormal distributions     Abnormal spectra

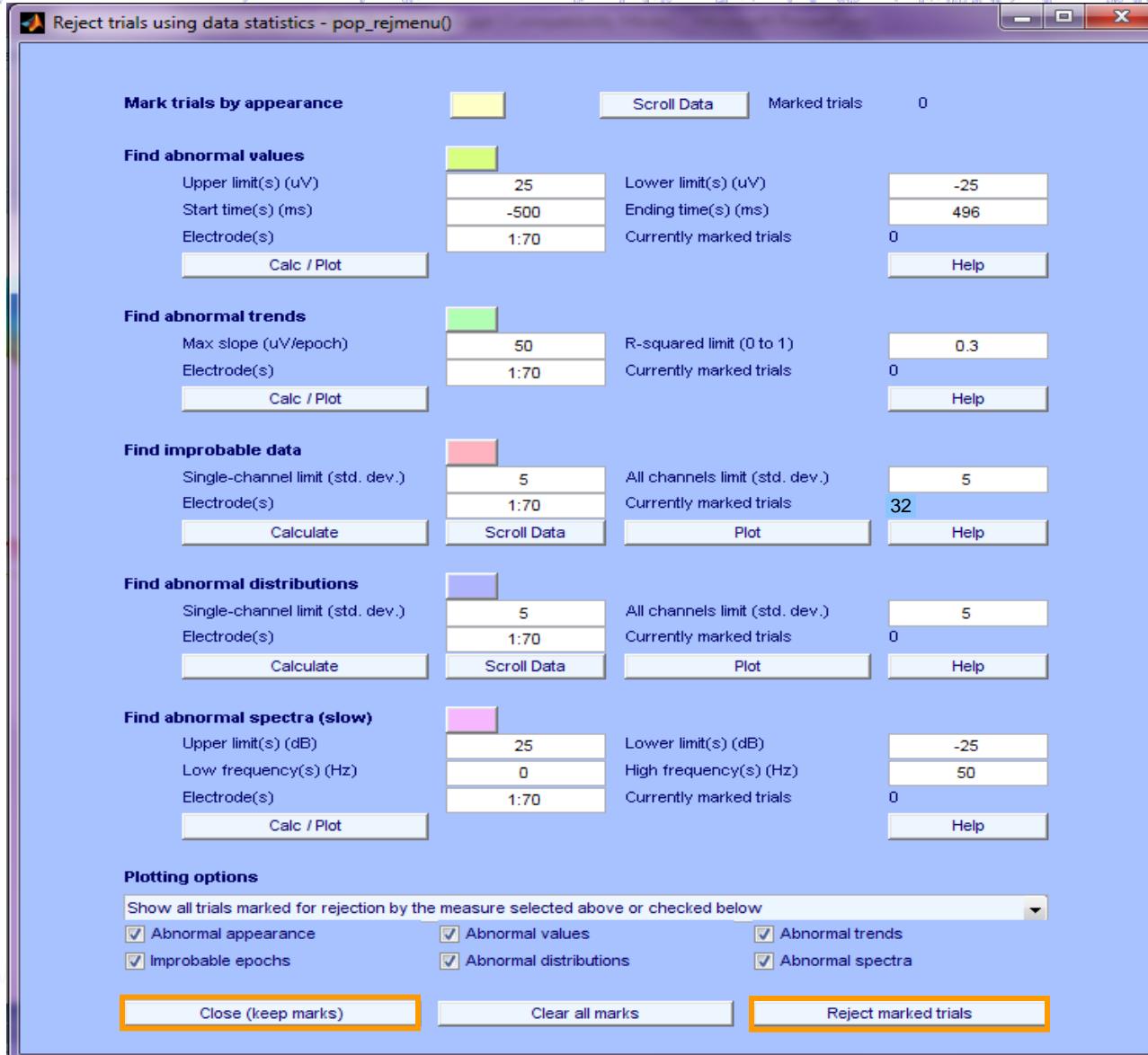
**Buttons:** Close (keep marks), Clear all marks, Reject marked trials



# Reject data epochs



# Reject or retain marked epochs



The screenshot shows the 'Reject trials using data statistics' dialog box from the EEGLAB software. The window title is 'Reject trials using data statistics - pop\_rejmenu()'.

**Mark trials by appearance**: A yellow bar progress indicator shows 0% completion. Buttons: 'Scroll Data' (disabled), 'Marked trials' (0), 'Calc / Plot' (disabled), 'Help' (disabled).

**Find abnormal values**: A green bar progress indicator shows 25% completion. Inputs: Upper limit(s) (uV) = 25, Start time(s) (ms) = -500, Electrode(s) = 1:70. Outputs: Lower limit(s) (uV) = -25, Ending time(s) (ms) = 496, Currently marked trials = 0. Buttons: 'Calc / Plot' (disabled), 'Help' (disabled).

**Find abnormal trends**: A green bar progress indicator shows 50% completion. Inputs: Max slope (uV/epoch) = 50, Electrode(s) = 1:70. Outputs: R-squared limit (0 to 1) = 0.3, Currently marked trials = 0. Buttons: 'Calc / Plot' (disabled), 'Help' (disabled).

**Find improbable data**: A red bar progress indicator shows 5% completion. Inputs: Single-channel limit (std. dev.) = 5, Electrode(s) = 1:70. Outputs: All channels limit (std. dev.) = 5, Currently marked trials = 32. Buttons: 'Calculate' (disabled), 'Scroll Data' (disabled), 'Plot' (disabled), 'Help' (disabled).

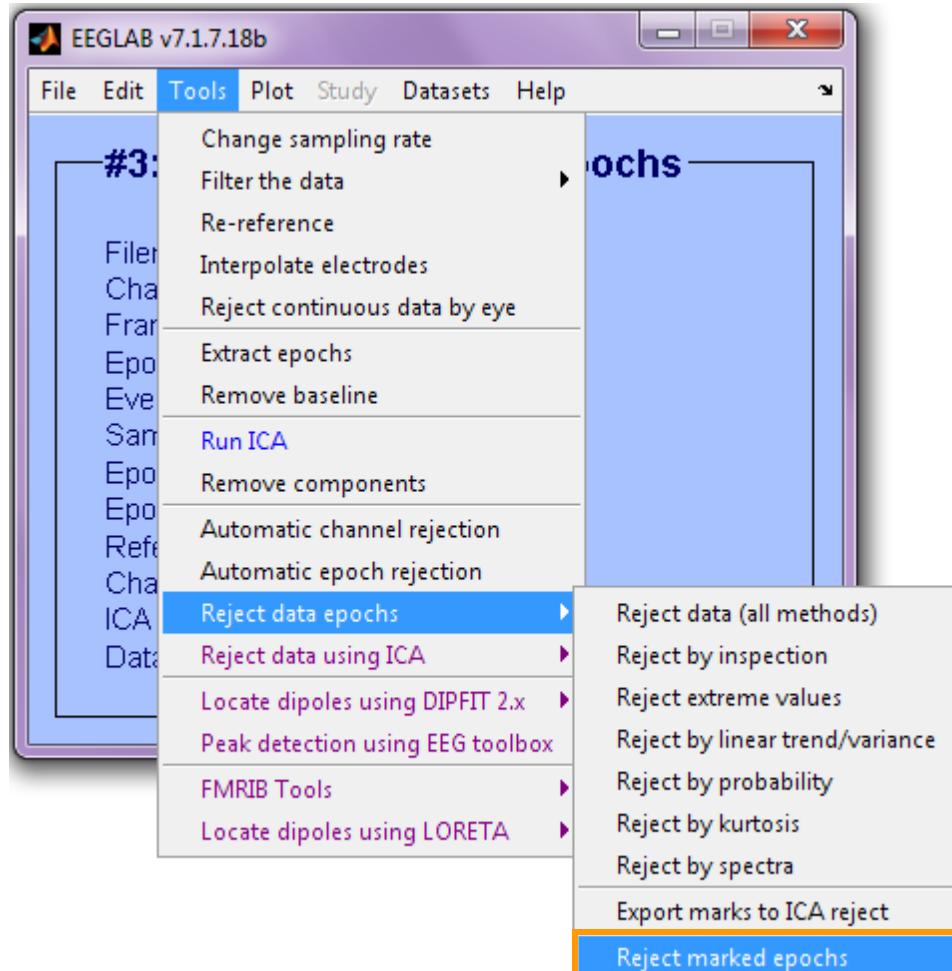
**Find abnormal distributions**: A purple bar progress indicator shows 5% completion. Inputs: Single-channel limit (std. dev.) = 5, Electrode(s) = 1:70. Outputs: All channels limit (std. dev.) = 5, Currently marked trials = 0. Buttons: 'Calculate' (disabled), 'Scroll Data' (disabled), 'Plot' (disabled), 'Help' (disabled).

**Find abnormal spectra (slow)**: A pink bar progress indicator shows 25% completion. Inputs: Upper limit(s) (dB) = 25, Low frequency(s) (Hz) = 0, Electrode(s) = 1:70. Outputs: Lower limit(s) (dB) = -25, High frequency(s) (Hz) = 50, Currently marked trials = 0. Buttons: 'Calc / Plot' (disabled), 'Help' (disabled).

**Plotting options**: A dropdown menu: 'Show all trials marked for rejection by the measure selected above or checked below'. Checkboxes: Abnormal appearance (checked), Abnormal values (checked), Abnormal trends (checked), Improbable epochs (checked), Abnormal distributions (checked), Abnormal spectra (checked). Buttons: 'Close (keep marks)' (highlighted with orange border), 'Clear all marks', 'Reject marked trials' (highlighted with orange border).

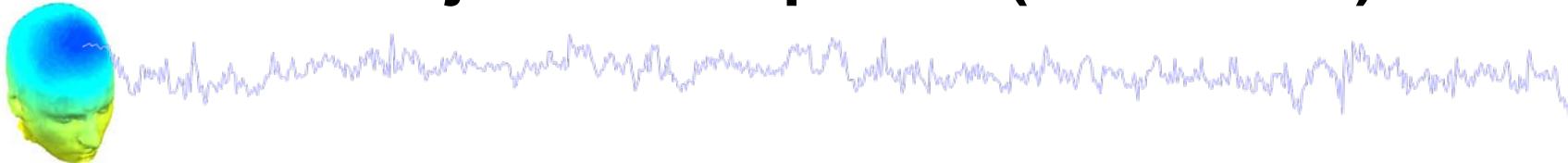


# Reject marked epochs



```
>> EEG = pop_jointprob(EEG,1,[1:70],5,5,0,0);
>> EEG = pop_rejepoch(EEG,find(EEG.reject.rejglobal),0);
```

# Reject data epochs (automatic)



EEGLAB v7.1.7.18b

File Edit Tools Plot Study Datasets Help

#3:

- Filter
- Ch
- Fra
- Epo
- Eve
- San
- Epo
- Epo
- Refe
- Cha
- ICA
- Data

Change sampling rate  
Filter the data  
Re-reference  
Interpolate electrodes  
Reject continuous data by eye  
Extract epochs  
Remove baseline  
Run ICA  
Remove components  
Automatic channel rejection  
**Automatic epoch rejection**  
Reject data epochs  
Reject data using ICA  
Locate dipoles using DIPFIT 2.x  
Peak detection using EEG toolbox  
FMRIB Tools  
Locate dipoles using LORETA

Epochs

Automatic artifact rejection -- pop\_autorej()

Detection of extremely large fluctuations (channels only)  
Threshold limit (microV)

Detection of unprobable activity (channels or ICA)  
Do not use these channel indices (default=all)  
Use these ICA components instead of data channels  
Probability threshold (std. dev.)   
Maximum % of total trials to reject per iteration

Check box for visual inspection of results

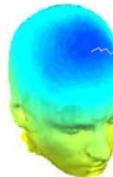
Cancel Help Ok

High enough to keep eye blinks

High standard deviation, multiples passes

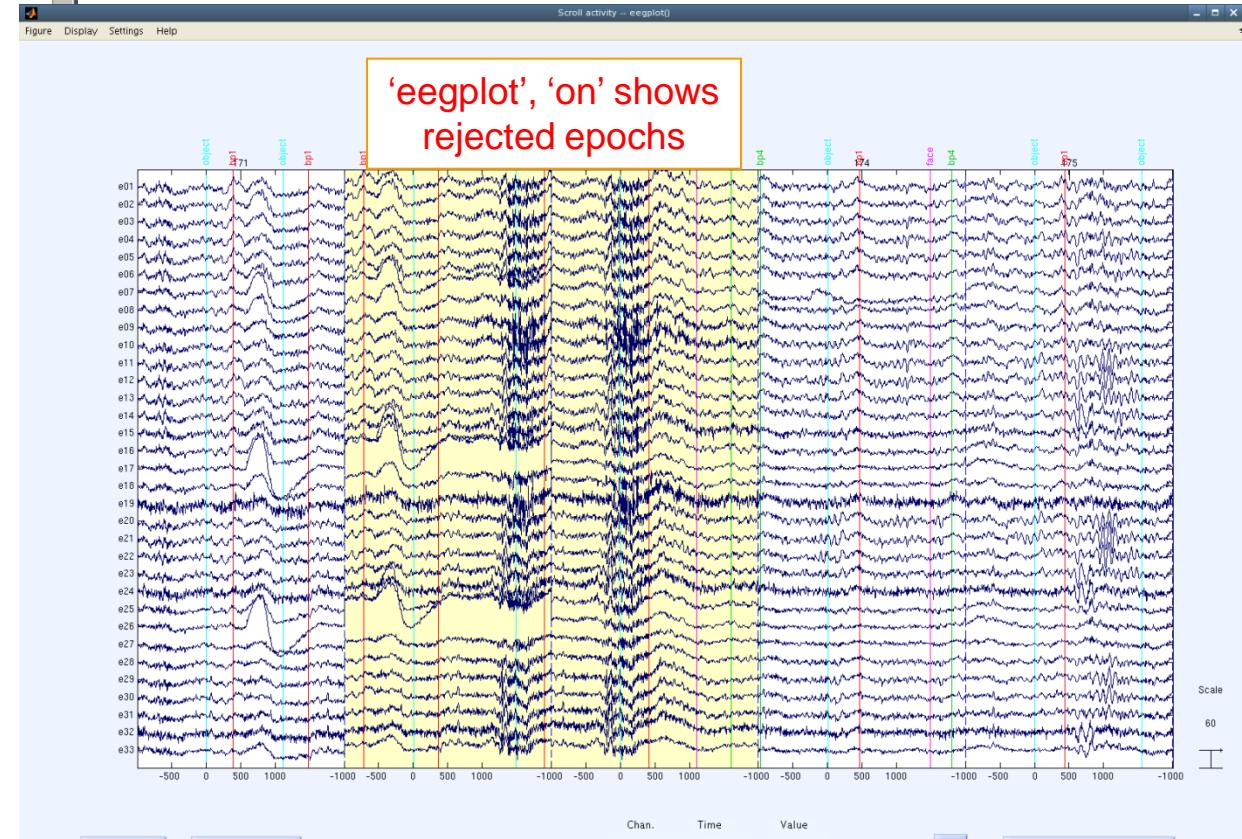
```
>> EEG = pop_autorej(EEG, 'nogui', 'on', 'eegplot', 'on');
```

# Reject data epochs (automatic)

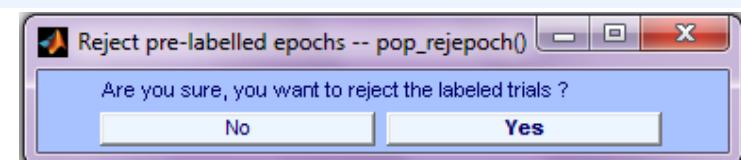


```
julie@doing:/home/julie
File Edit View Terminal Tabs Help
>>
Running auto-rejection protocol...
33 channel selected
0/182 trials marked for rejection
Computing joint probability for channels...
Computing all-channel probability...
5/182 trials marked for rejection
5 trials marked for rejection
5/182 trials rejected
Removing 5 trial(s)...
Pop_select: removing 22 unreferenced events
Computing joint probability for channels...
Computing all-channel probability...
3/177 trials marked for rejection
3 trials marked for rejection
3/177 trials rejected
Removing 3 trial(s)...
Pop_select: removing 14 unreferenced events
Computing joint probability for channels...
Computing all-channel probability...
4/174 trials marked for rejection
4 trials marked for rejection
4/174 trials rejected
Removing 4 trial(s)...
Pop_select: removing 16 unreferenced events
Computing joint probability for channels...
Computing all-channel probability...
3/170 trials marked for rejection
3 trials marked for rejection
3/170 trials rejected
Removing 3 trial(s)...
Pop_select: removing 14 unreferenced events
Computing joint probability for channels...
Computing all-channel probability...
3/167 trials marked for rejection
3 trials marked for rejection
3/167 trials rejected
Removing 3 trial(s)...
Pop_select: removing 12 unreferenced events
Computing joint probability for channels...
Computing all-channel probability...
1/164 trials marked for rejection
1 trials marked for rejection
1/164 trials rejected
Removing 1 trial(s)...
Pop_select: removing 4 unreferenced events
Computing joint probability for channels...
Computing all-channel probability...
0/163 trials marked for rejection
0 trials marked for rejection
0/163 trials rejected
Final kurtosis reject...
Computing kurtosis for channels...
Computing all-channel kurtosis...
3/163 trials marked for rejection
3 trials marked for rejection
>>
```

Iterative rejection  
based on probability



CANCEL Event types << < 171 > >> Chan. Time Value + - REJECT



# Artifact rejection and running ICA



## Task 1

Reject noisy data

## Task 2

Run ICA

## Task 3

Plot components

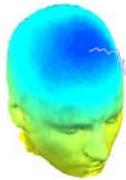
## Task 4

Remove components  
(i.e. back-projection)

## Exercise...



# Independent Component Analysis



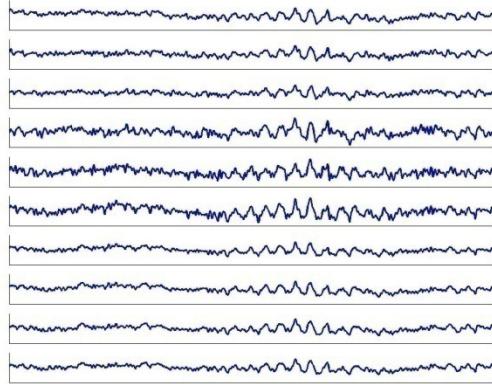
$x$  = scalp EEG

$W$  = unmixing matrix

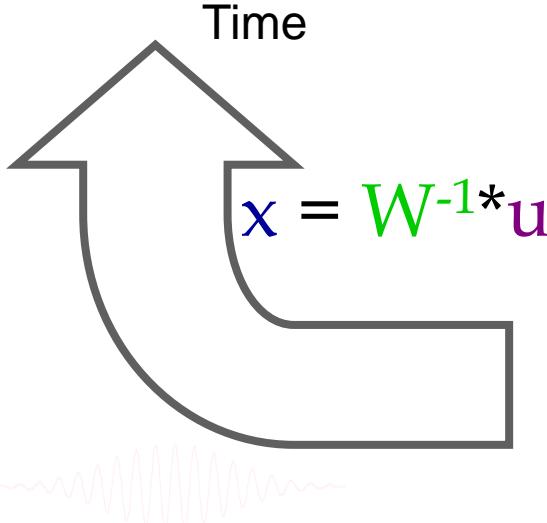
$u$  = sources



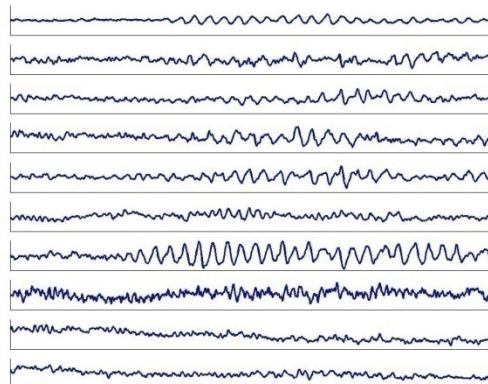
Channels



Time



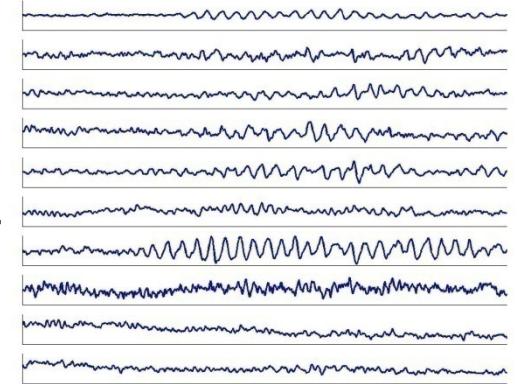
$u$  = sources



$$W^*x = u$$

ICA

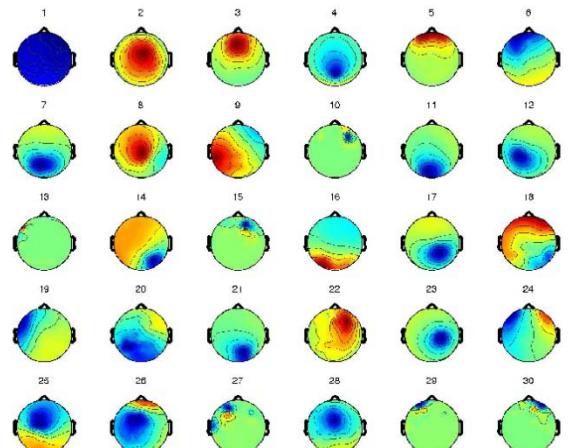
Components



Time

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

\*



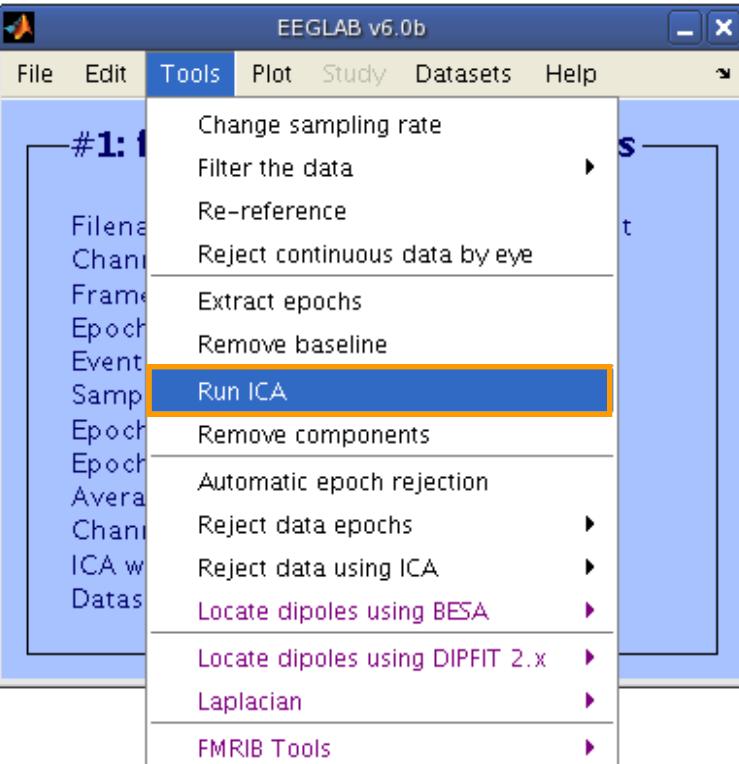
ICA Components

# “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)
- High-pass filter to remove slow drifts (no low-pass filter needed)
- Remove bad channels
- Data must be in double precision (not single)

# Runica options



Option	Default	Comments
'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, erica, sobi, acsobiro**



# Runica progress...



Press Button to interrupt runica

Interrupt

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 spherling matrix...
Starting weights are the identity matrix ...
Spherling 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

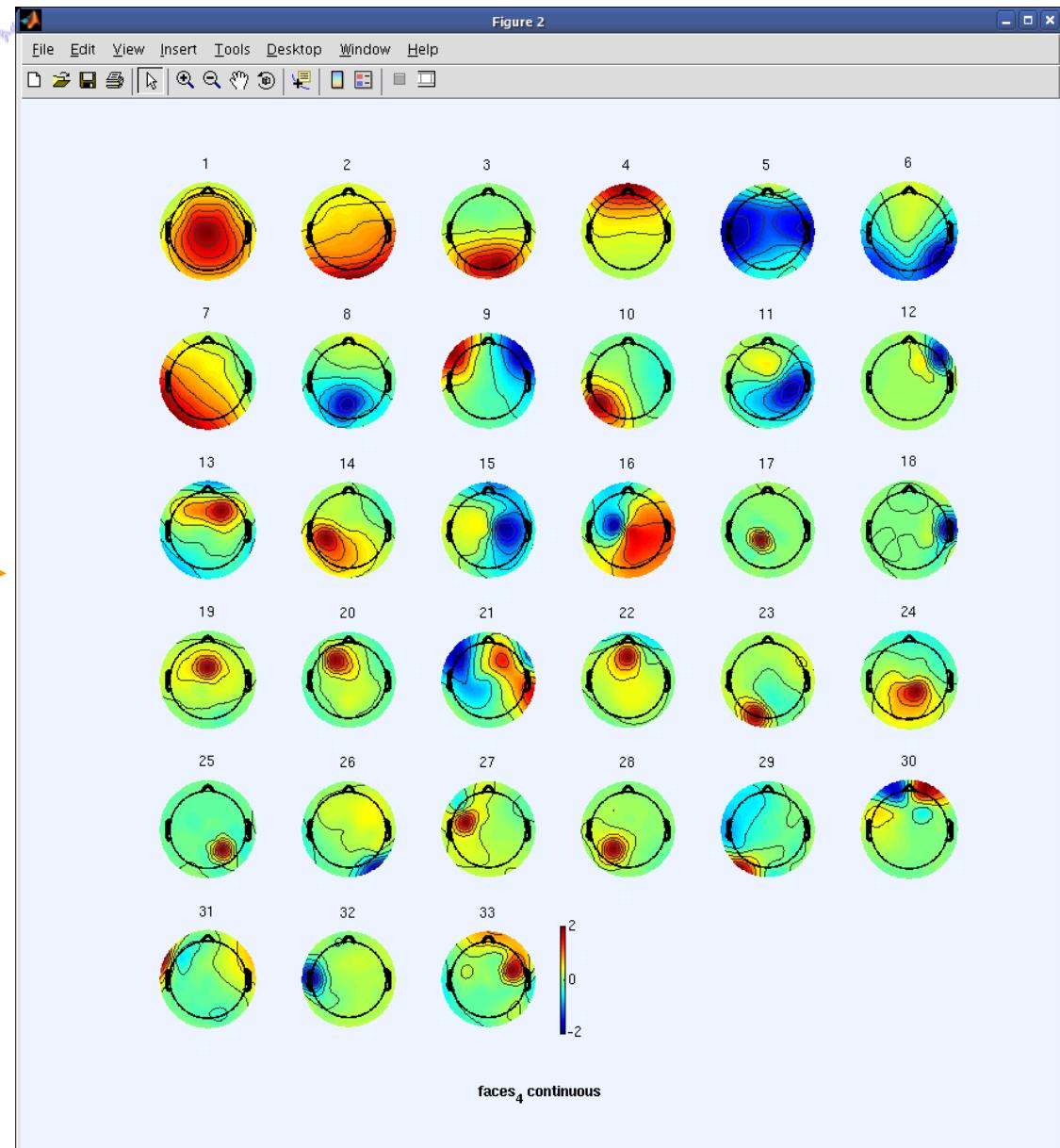
```
step 241 - lrate 0.000002, wchange 0.00000082, angledelta 101.5 deg
step 242 - lrate 0.000001, wchange 0.00000061, angledelta 96.1 deg
step 243 - lrate 0.000001, wchange 0.00000057, angledelta 97.5 deg
step 244 - lrate 0.000001, wchange 0.00000054, angledelta 93.7 deg
step 245 - lrate 0.000001, wchange 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

Terminal

```
File Edit View Terminal Tabs Help  
>> EEG  
  
EEG =  
  
    setname: 'faces_4 continuous'  
filename: 'faces_4.set'  
filepath: '/home/julie/workshop06/'  
subject: ''  
group: ''  
condition: ''  
session: []  
comments: [15x48 char]  
nbchan: 33  
trials: 1  
pnts: 133175  
srate: 250  
xmin: 0  
xmax: 532.6960  
times: []  
data: [33x133175 single]  
icaact: [33x133175 single]  
icawinv: [33x33 double]  
icasphere: [33x33 double]  
icaweights: [33x33 double]  
icachansind: [1x33 double]  
chanlocs: [1x33 struct]  
urchanlocs: []  
chaninfo: [1x1 struct]  
ref: 'common'  
event: [1x731 struct]  
urevent: [1x731 struct]  
eventdescription: {[[] []]}  
epoch: []  
epochdescription: {}  
reject: [1x1 struct]  
stats: [1x1 struct]  
specdata: []  
specicaact: []  
splinefile: ''  
icasplinefile: ''  
dipfit: [1x1 struct]  
history: [1x1633 char]  
saved: 'no'  
etc: []  
  
>>
```



# Artifact rejection and running ICA



## Task 1

Reject noisy data

## Task 2

Run ICA

## Task 3

Plot components

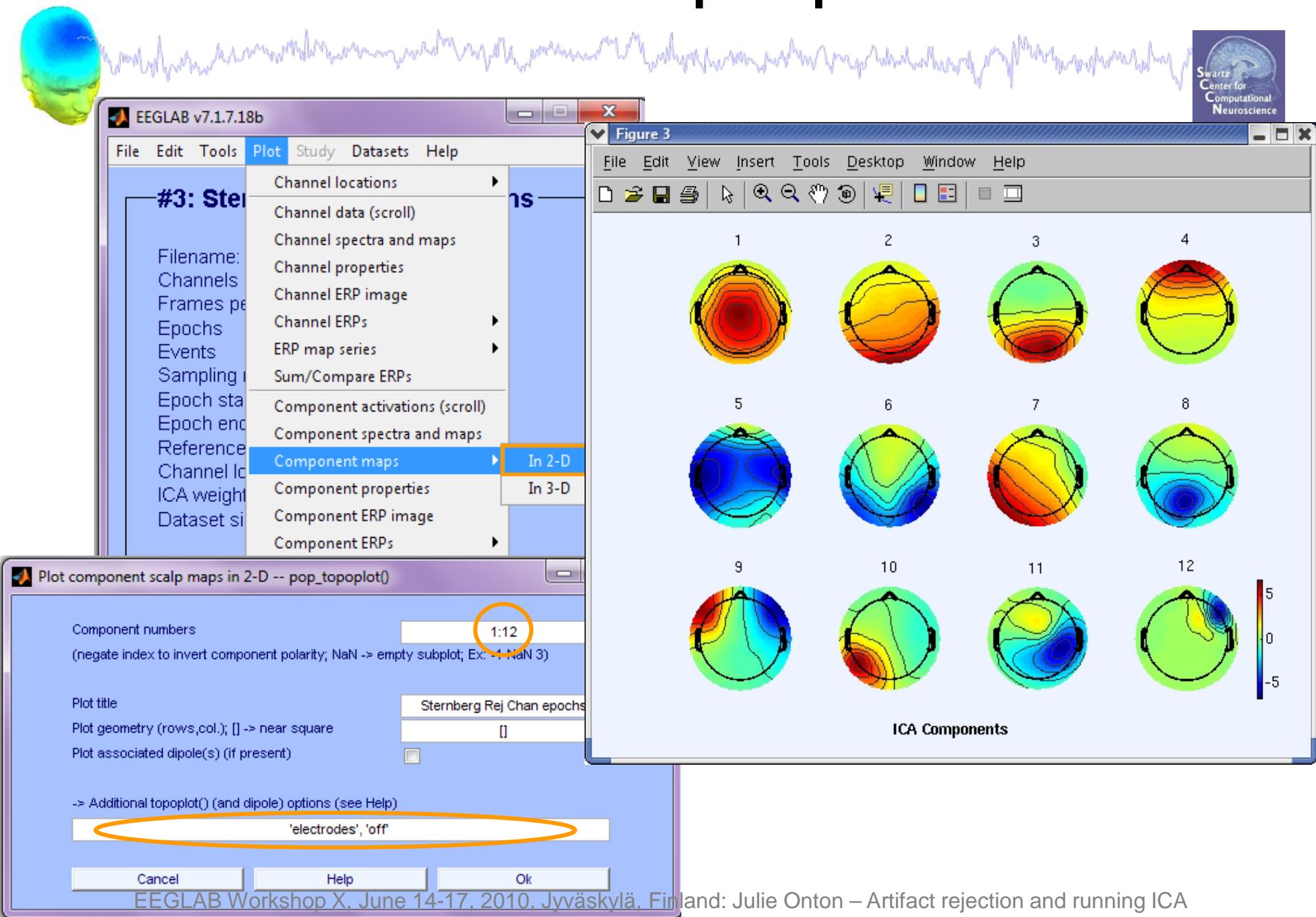
## Task 4

Remove components  
(i.e. back-projection)

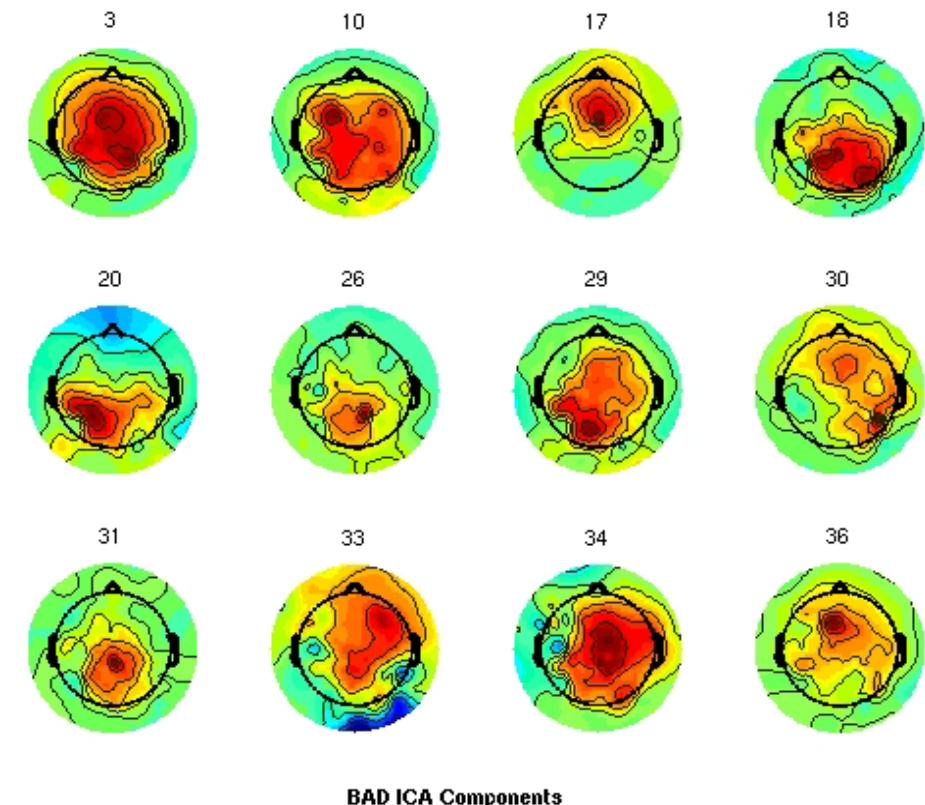
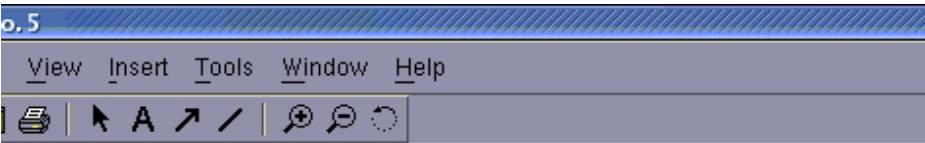
## Exercise...



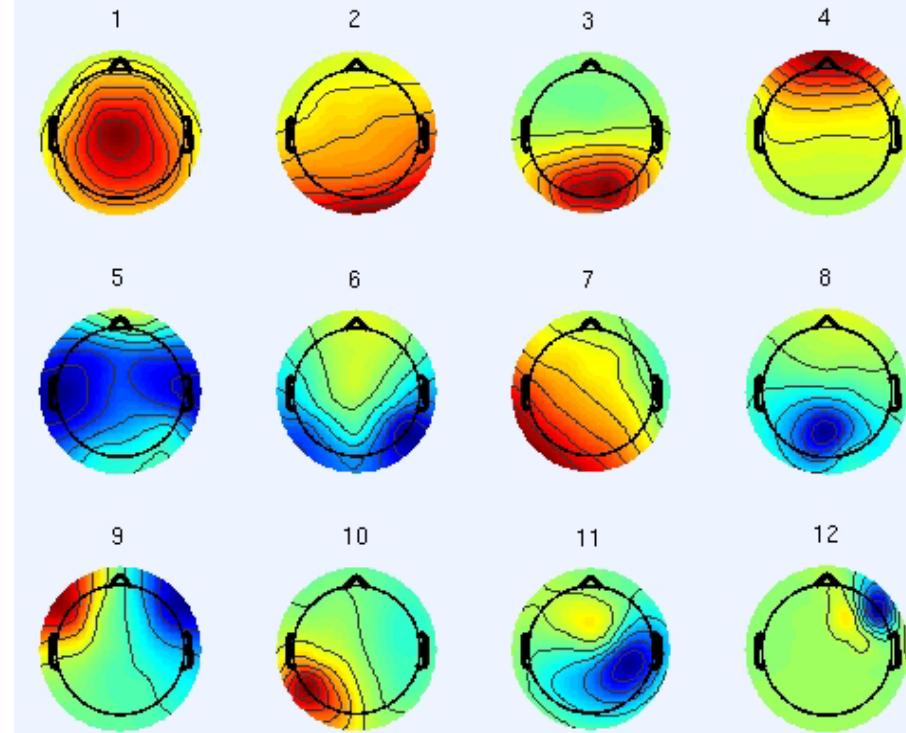
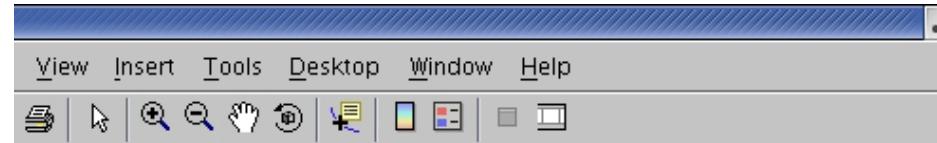
# Plot ICA scalp maps



# Compare 'good' and 'bad' scalp maps

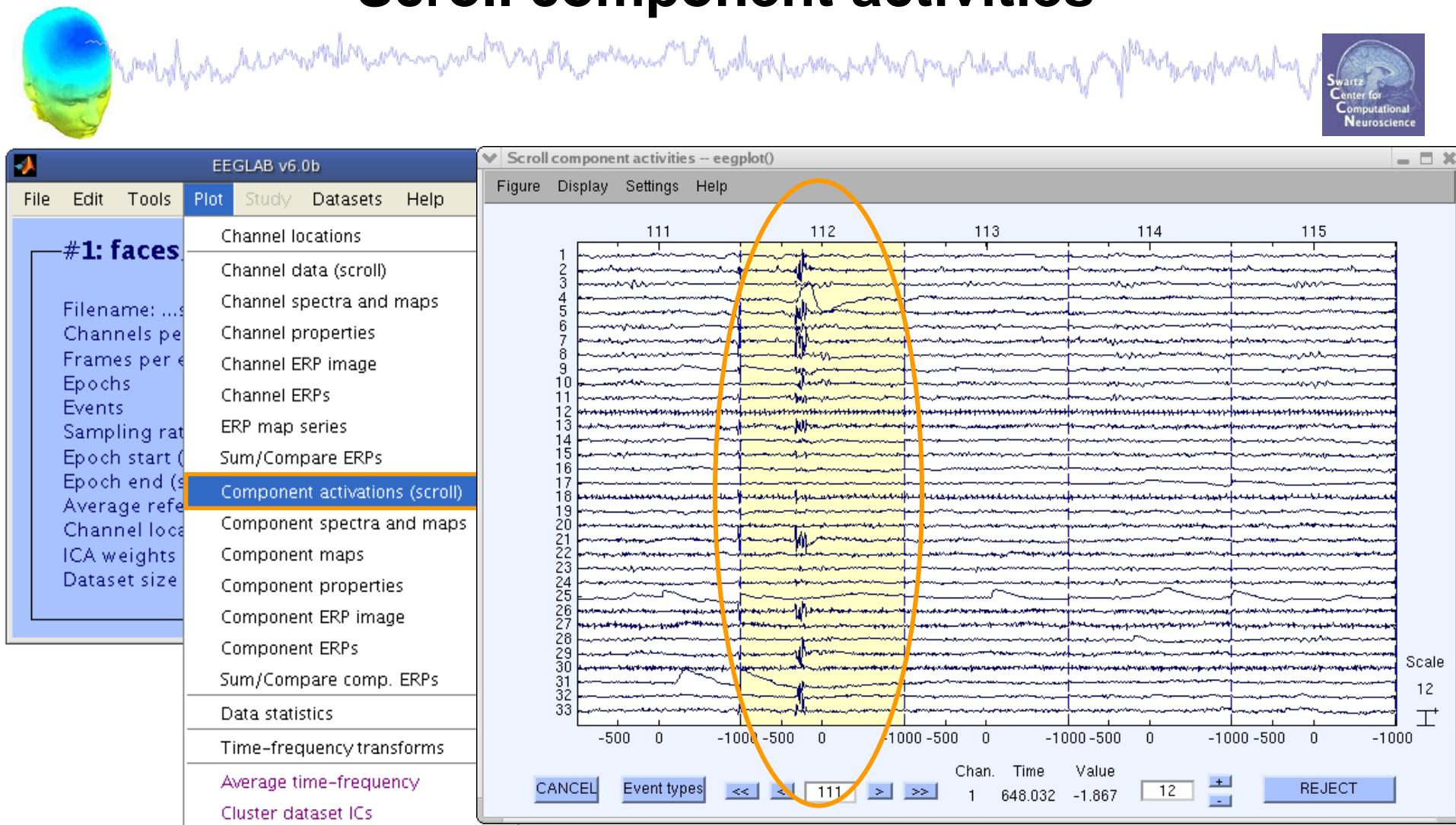


BAD ICA Components

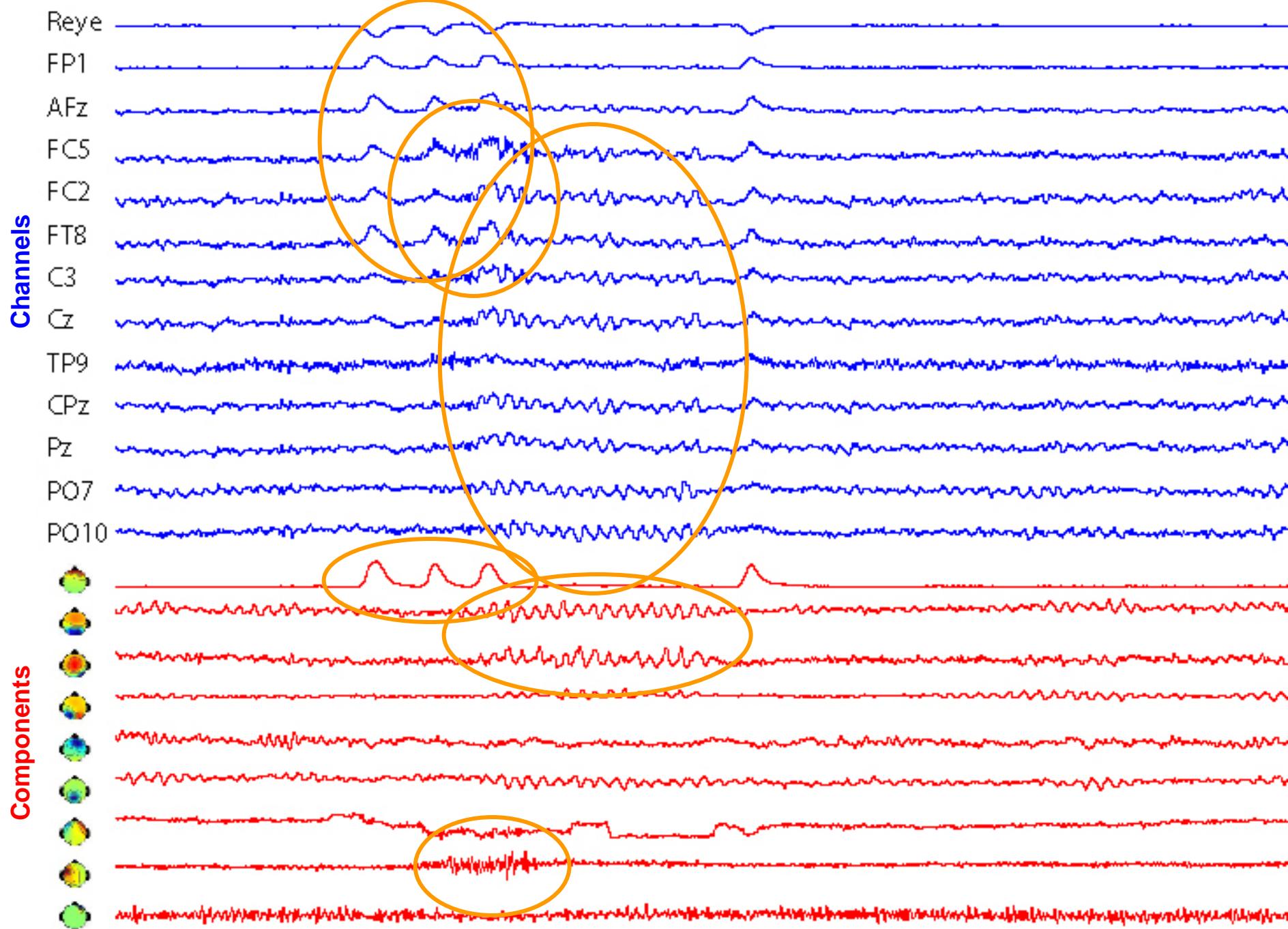


ICA Components

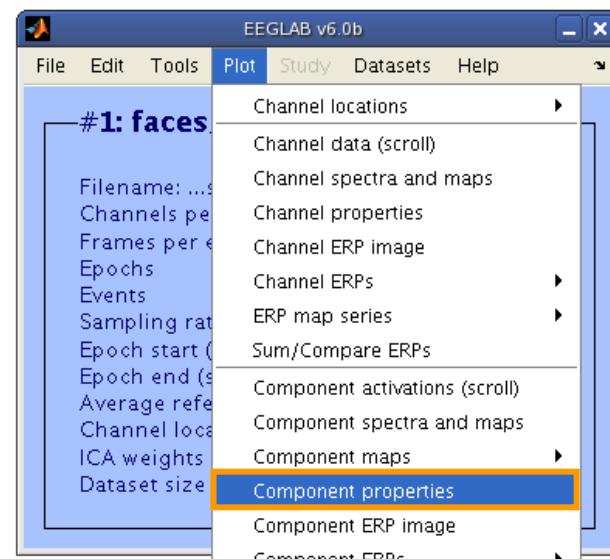
# Scroll component activities



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



# Plot ICA component properties

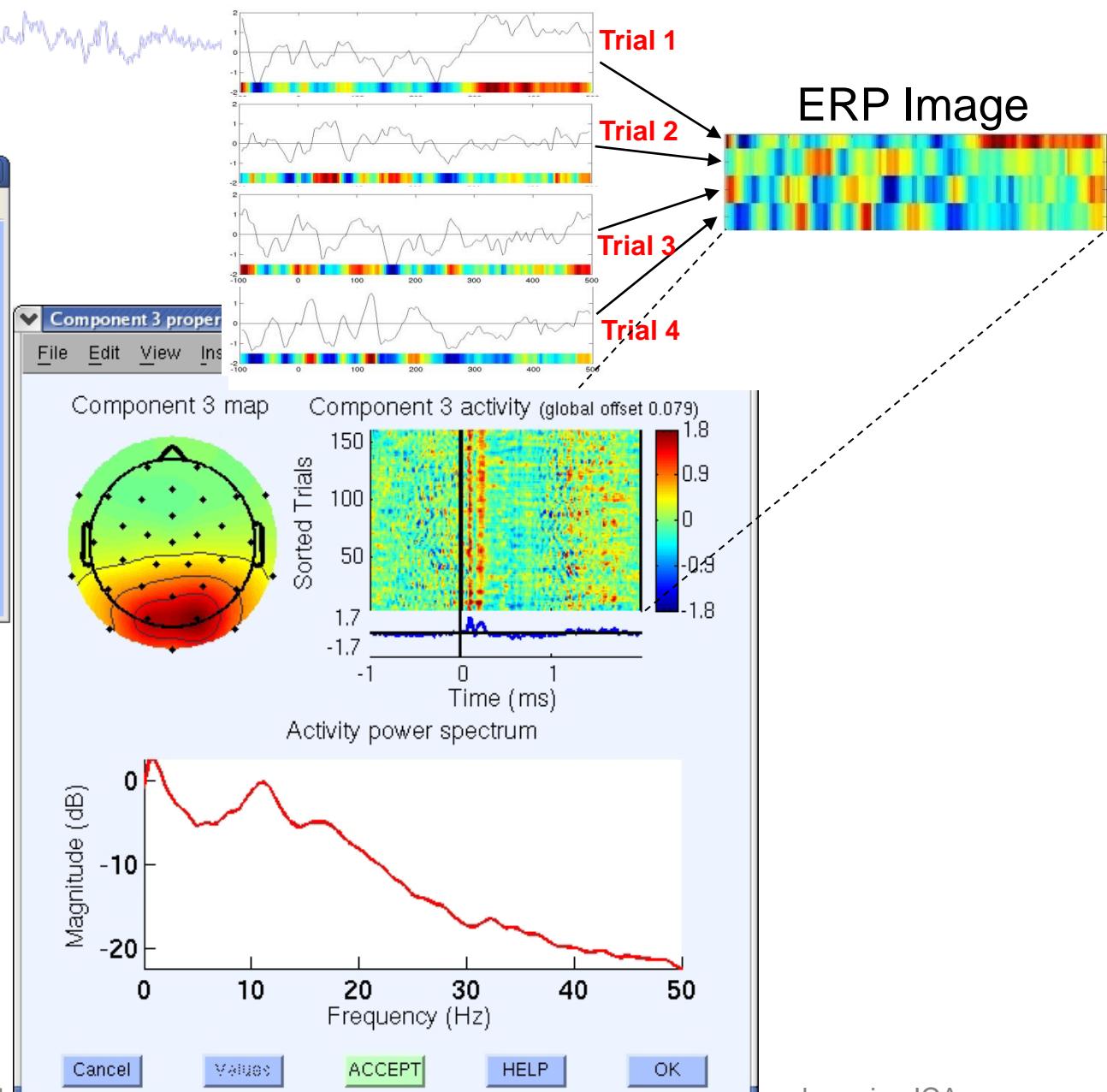


Component properties – po

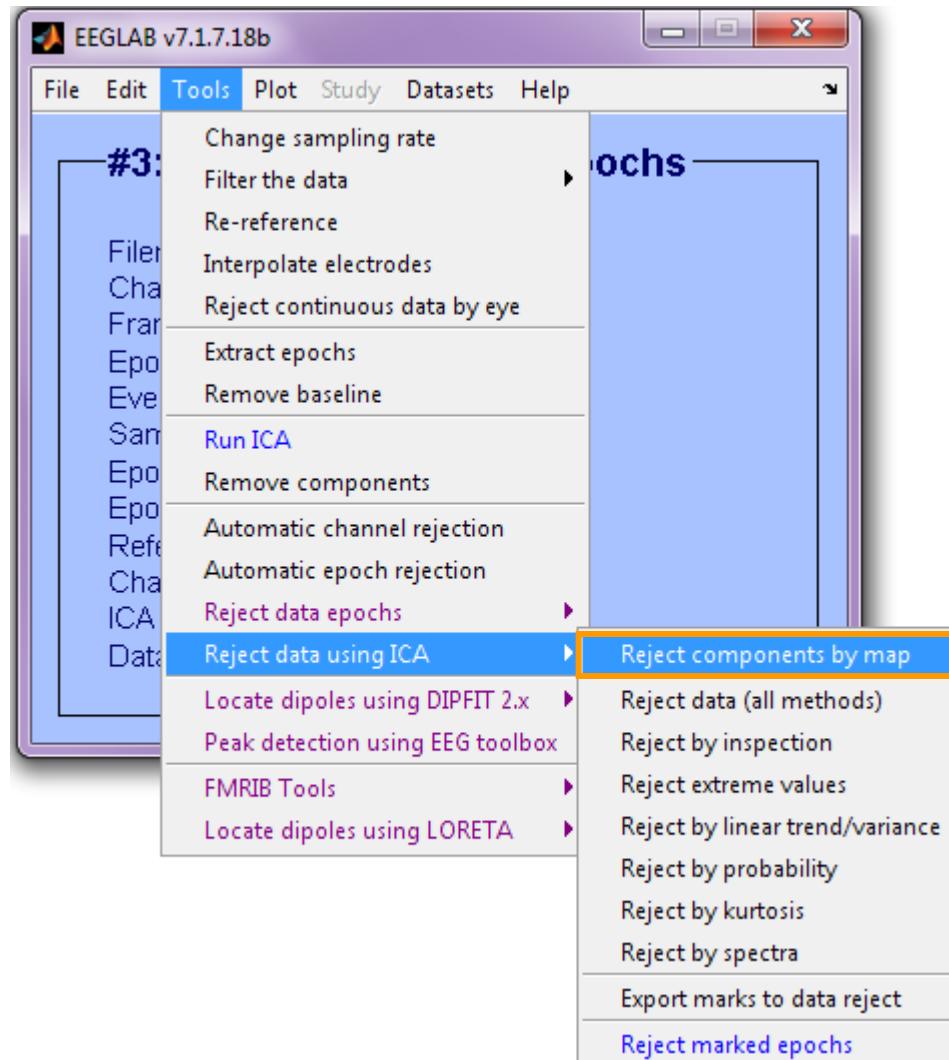
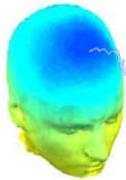
Component number to plot:

3

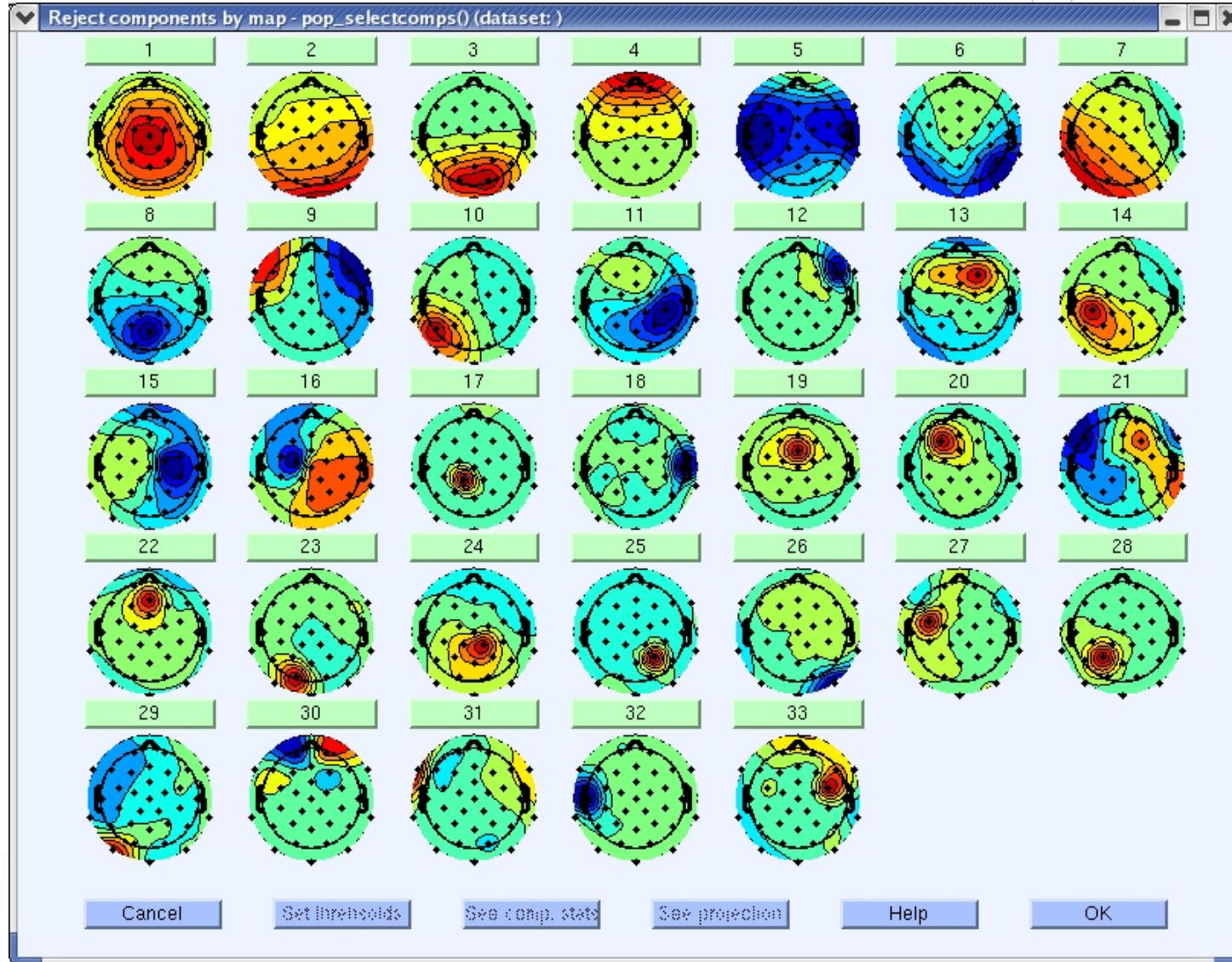
Cancel Help Ok

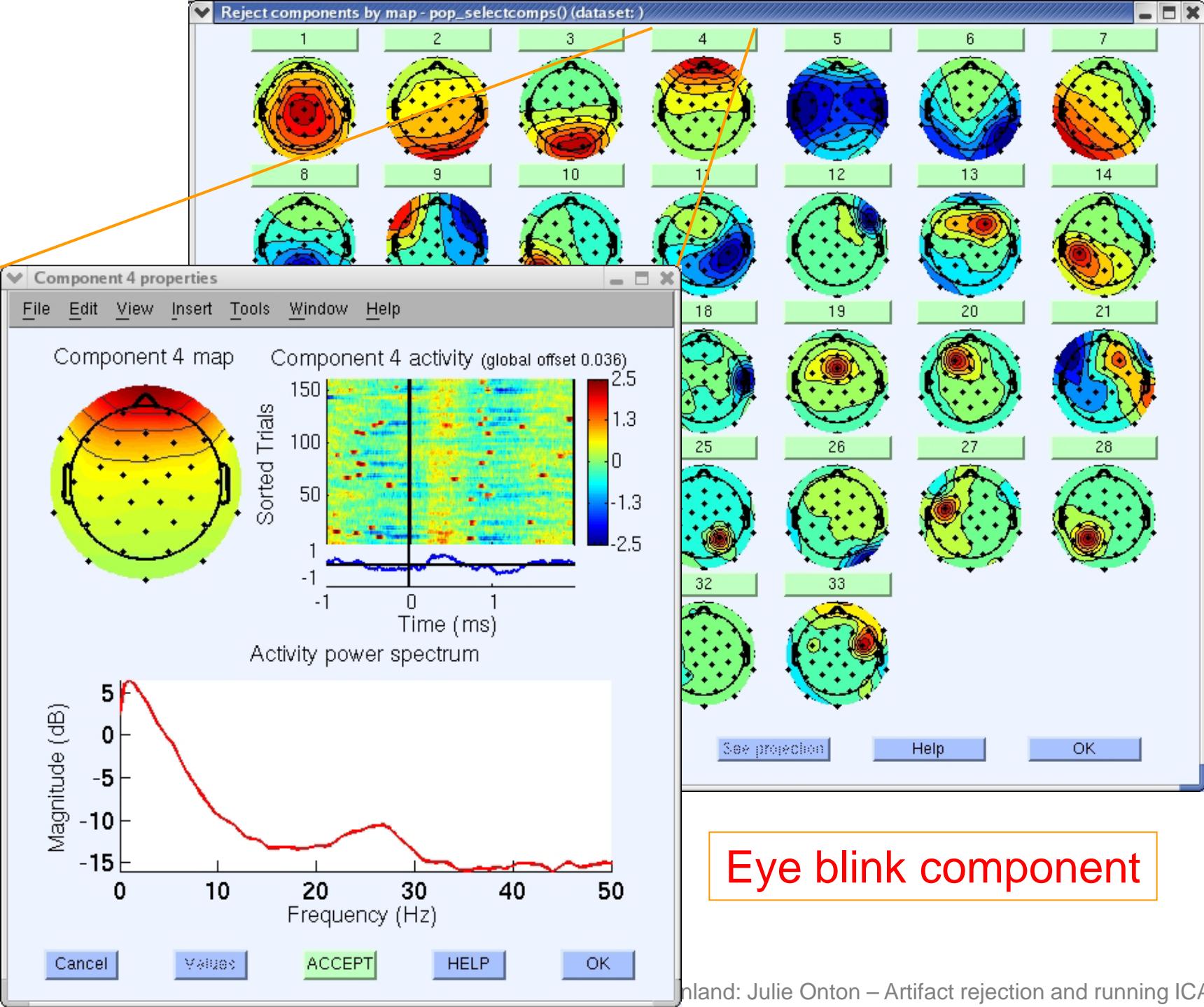


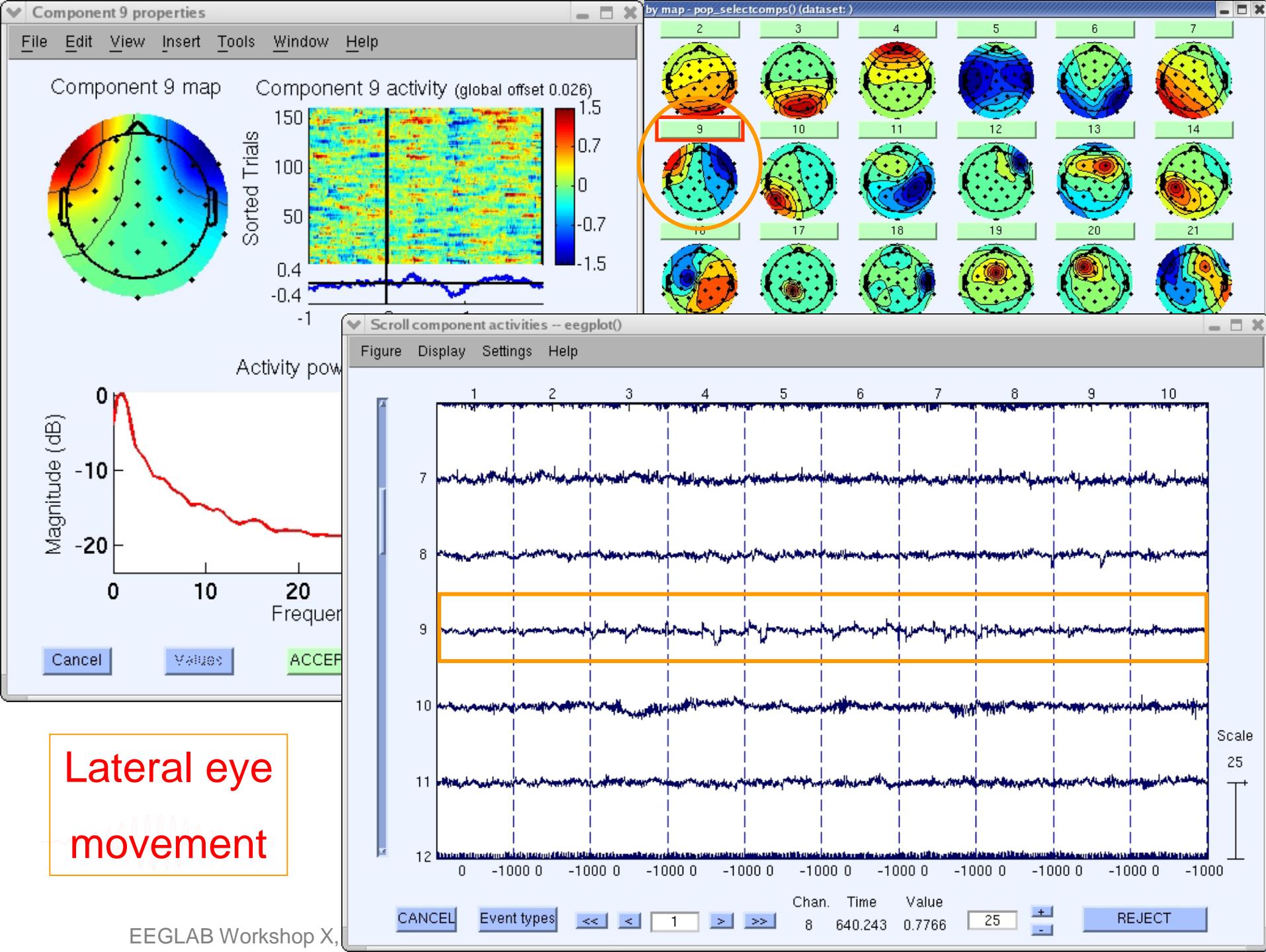
# Reviewing component properties

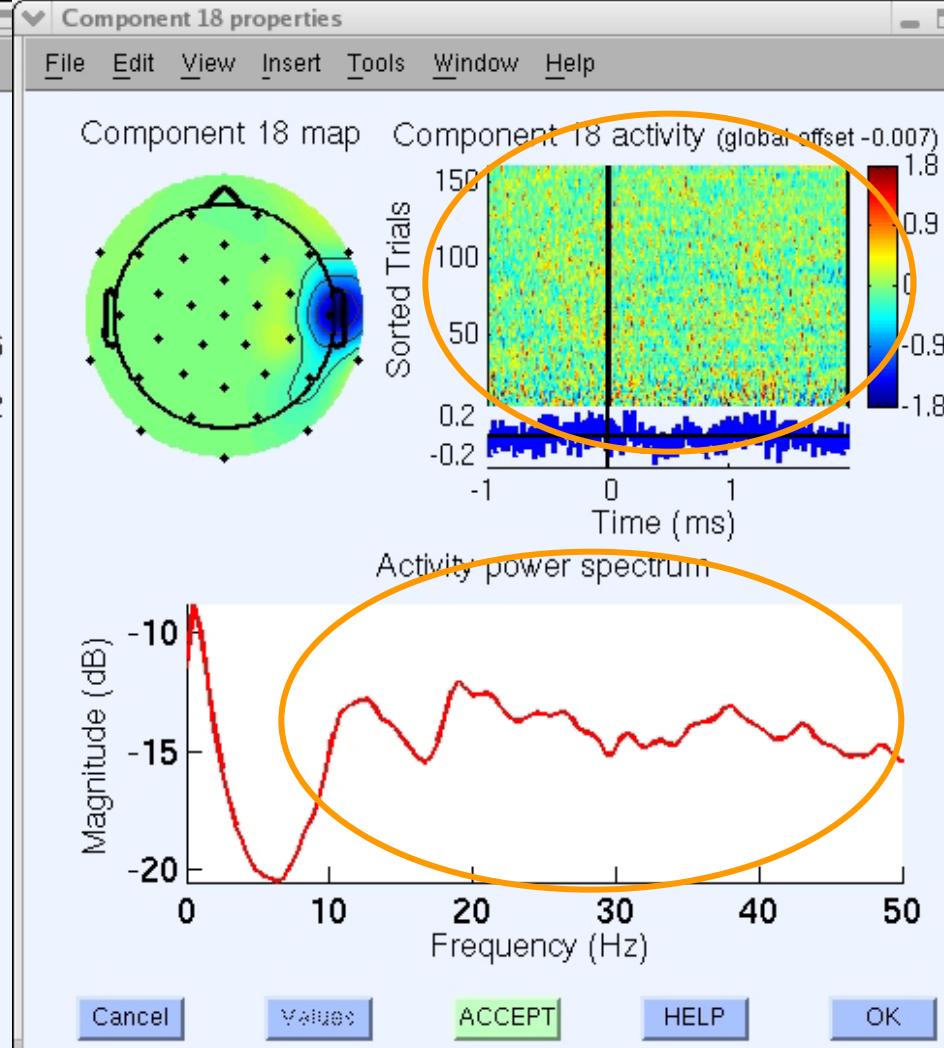
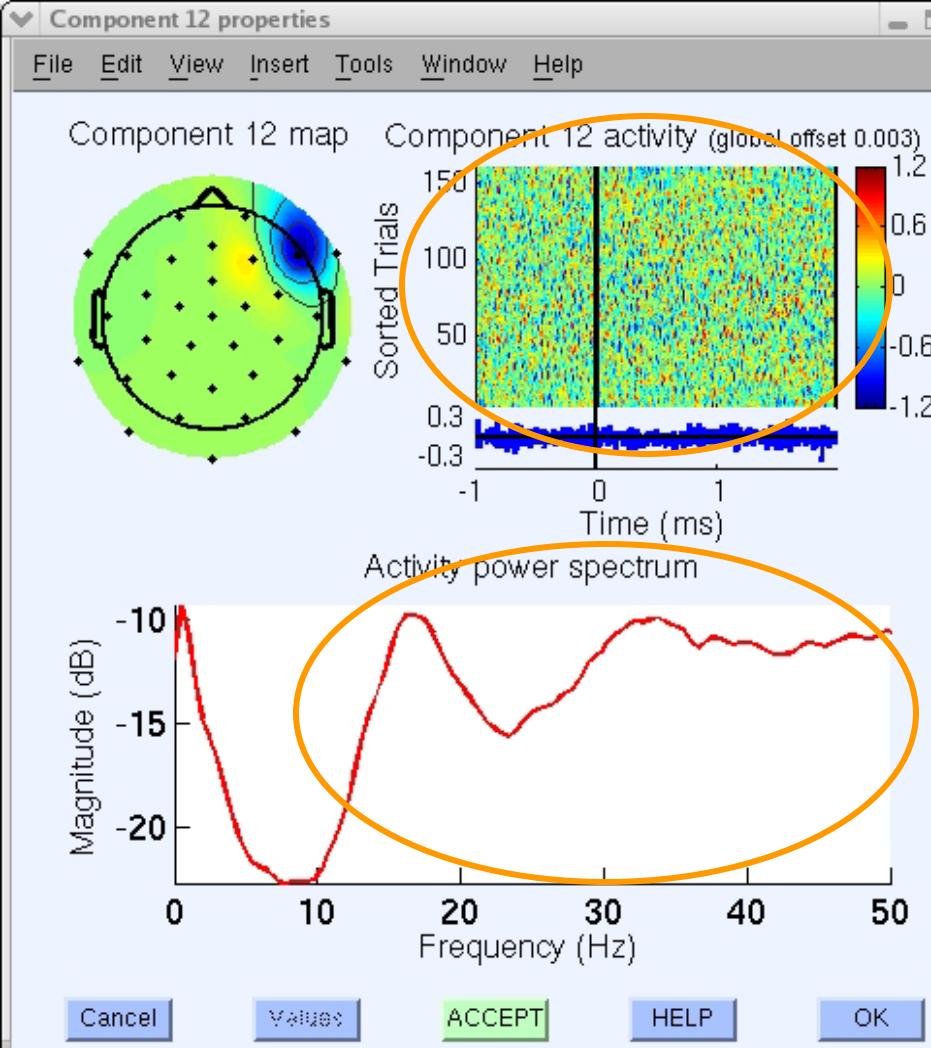
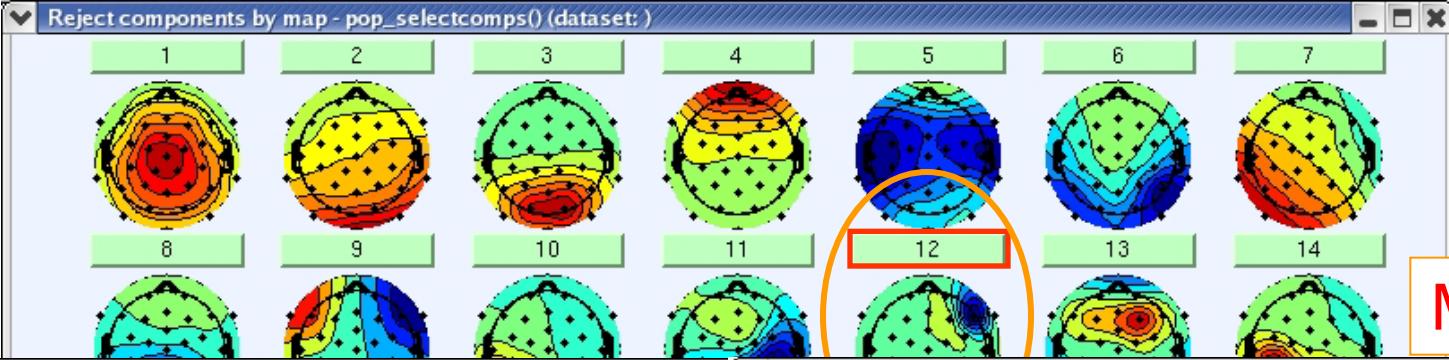


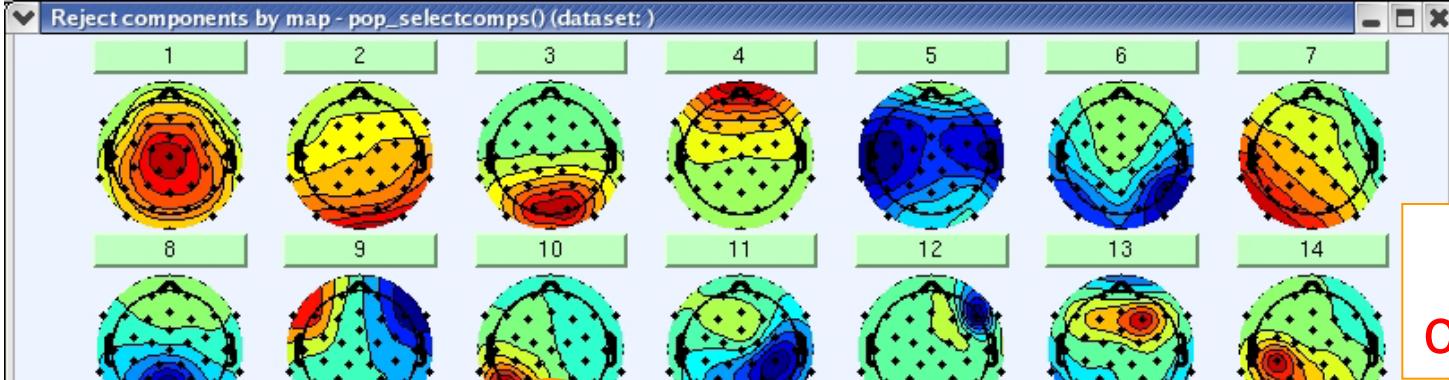
# Component scalp maps/properties



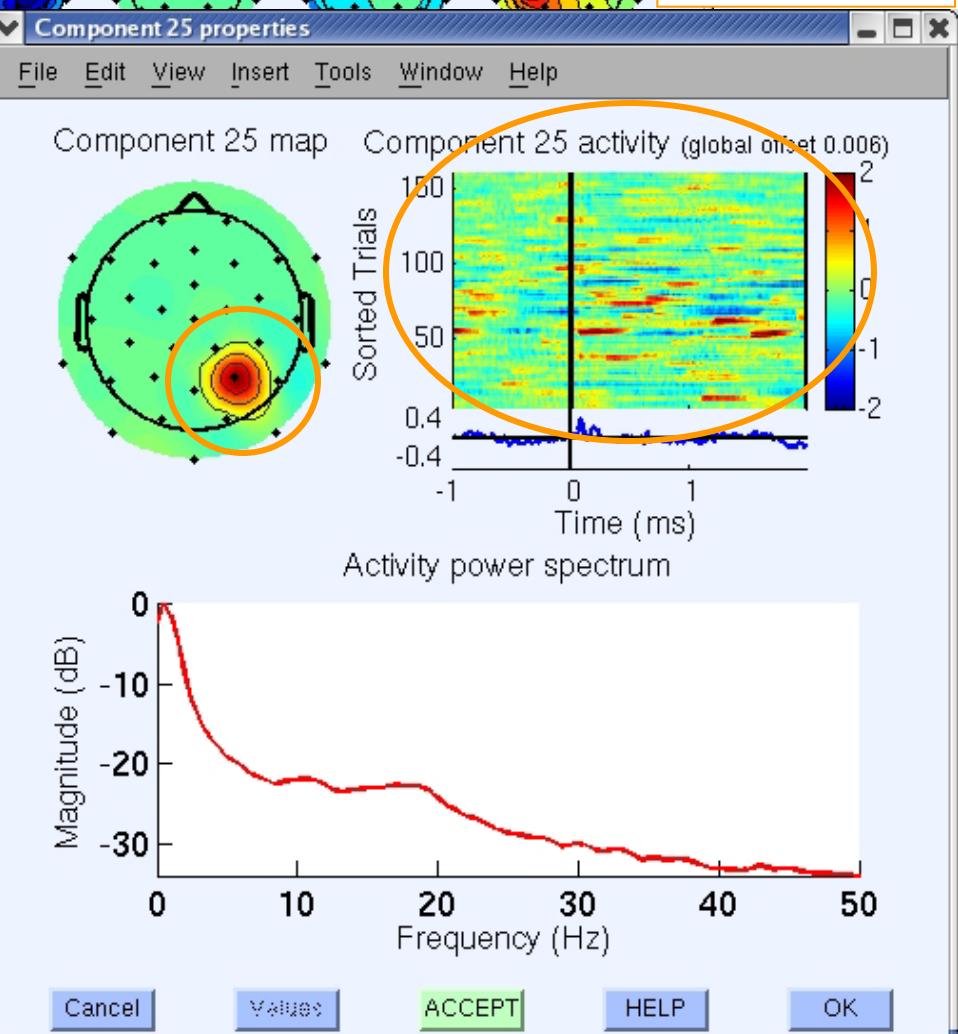
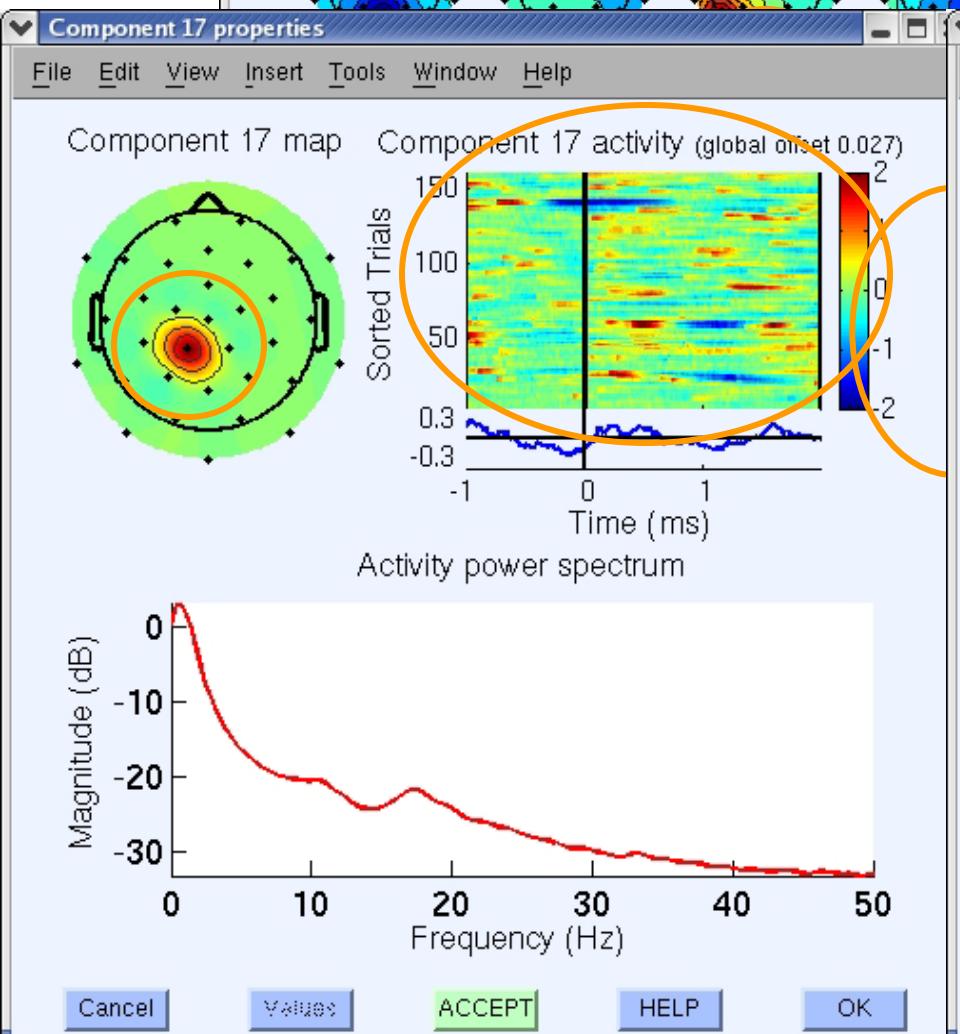


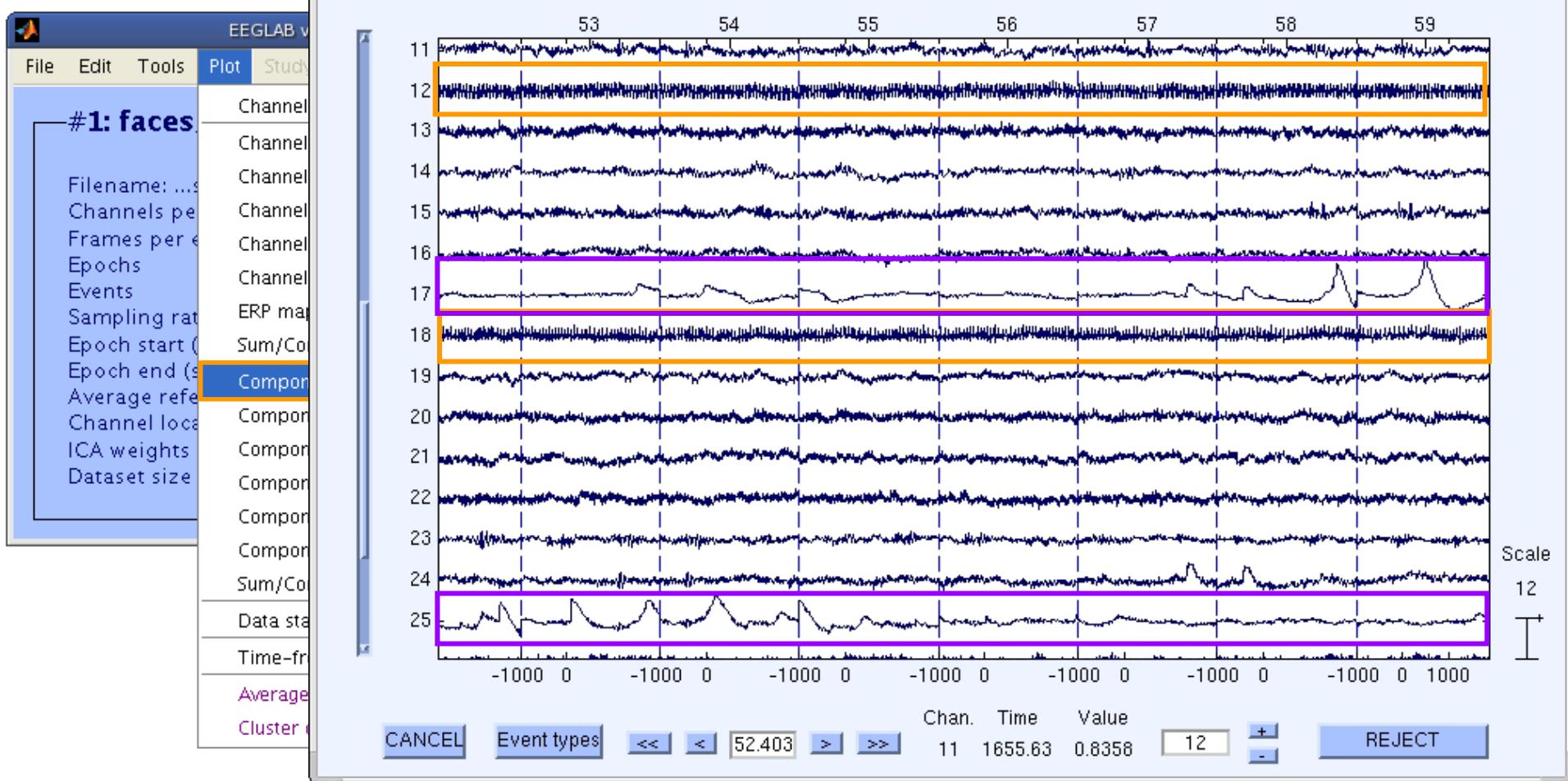
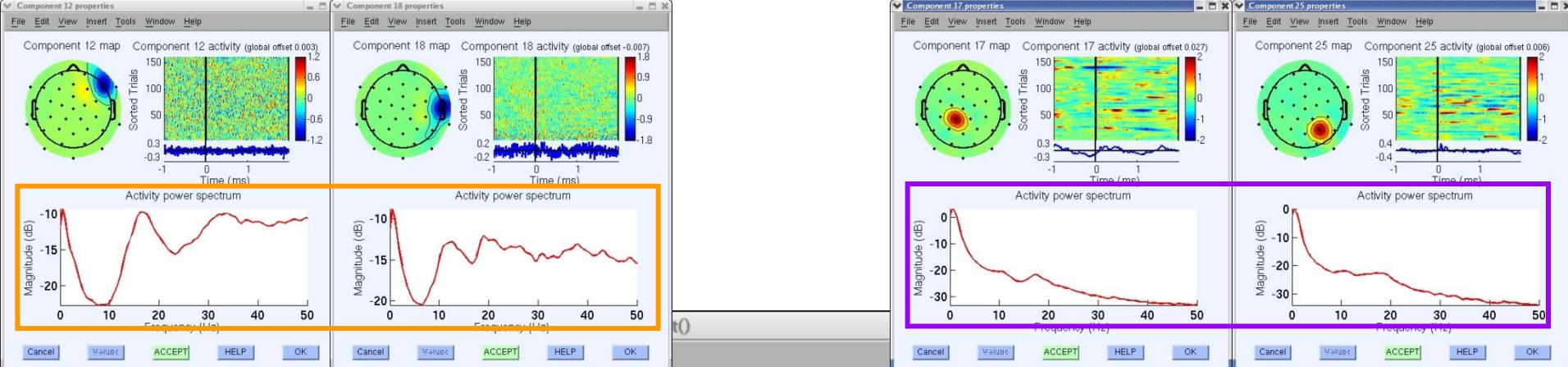


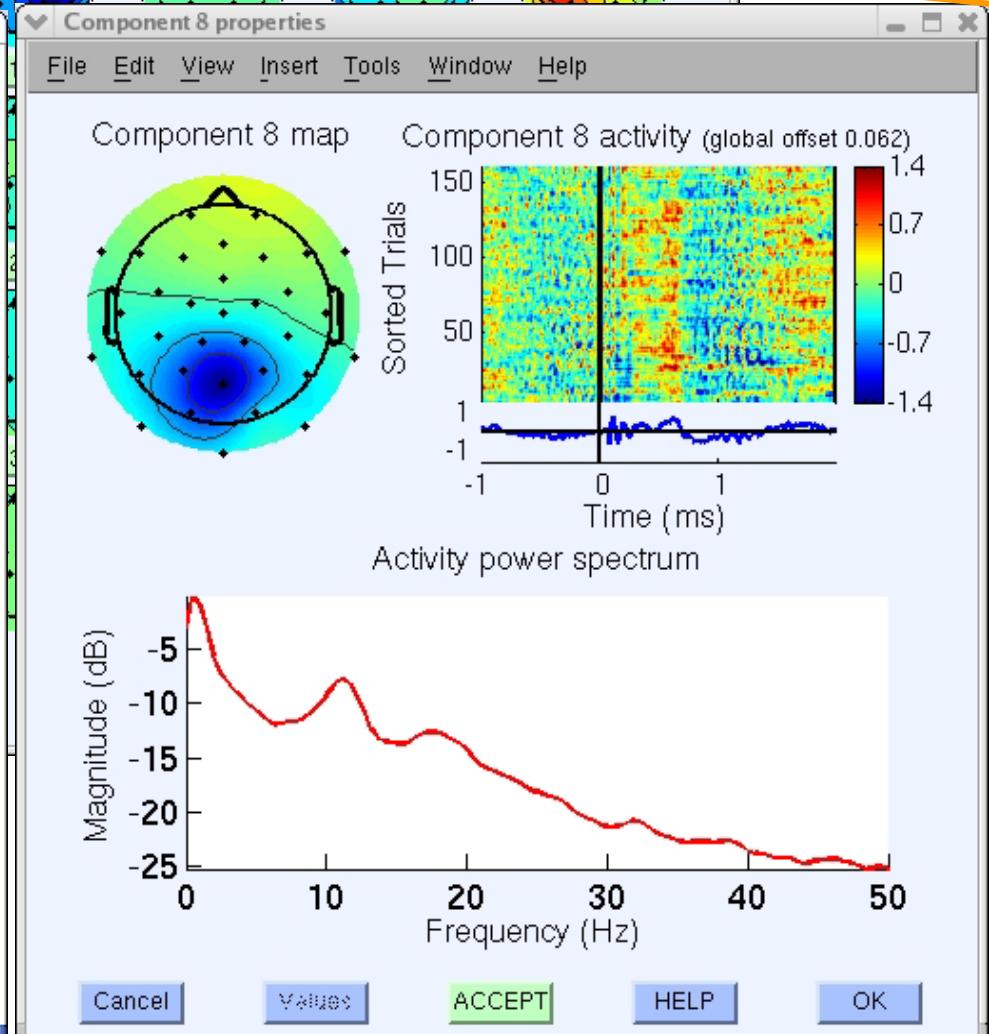
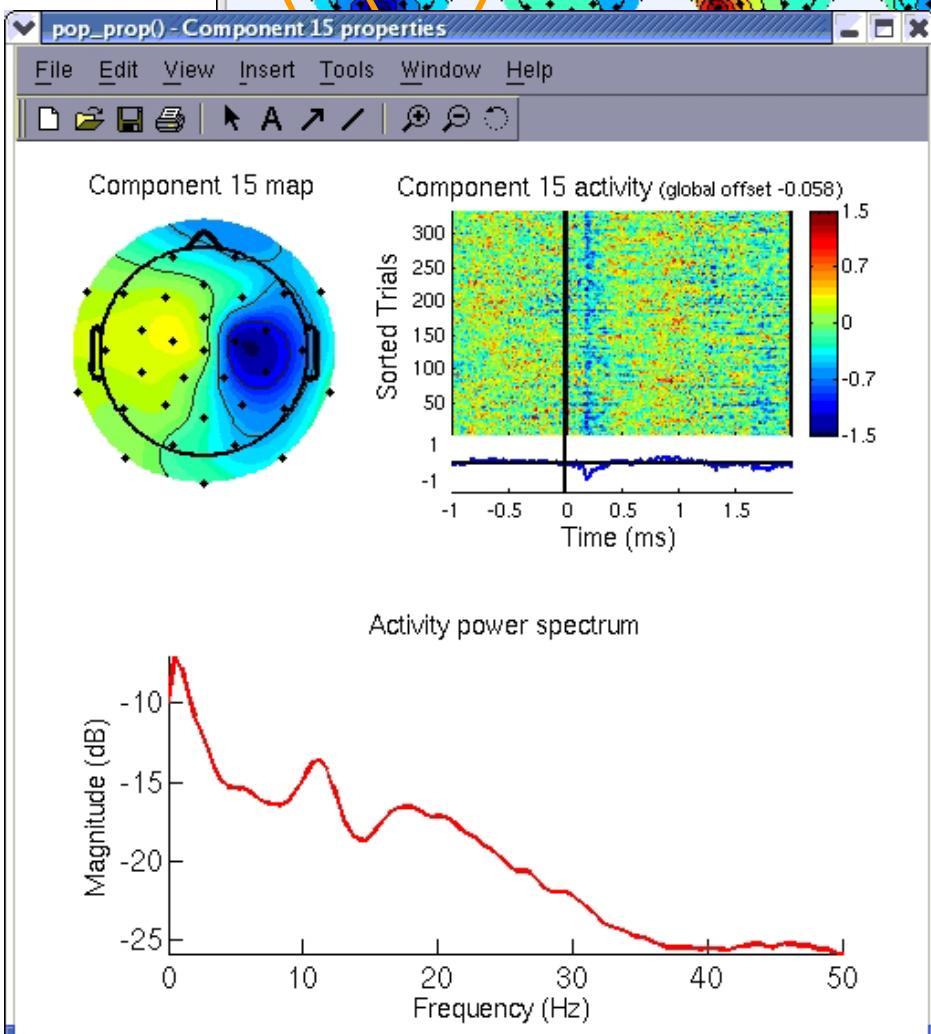
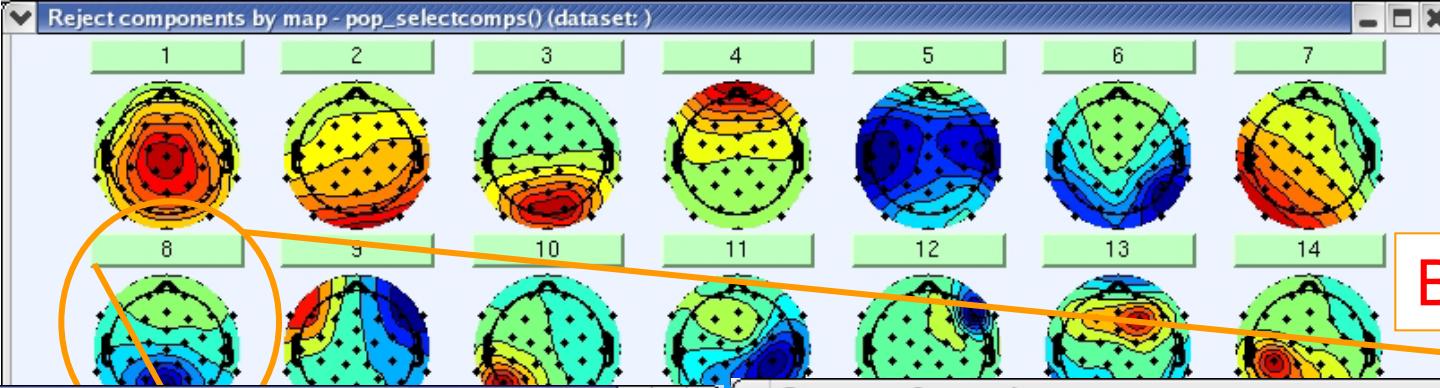




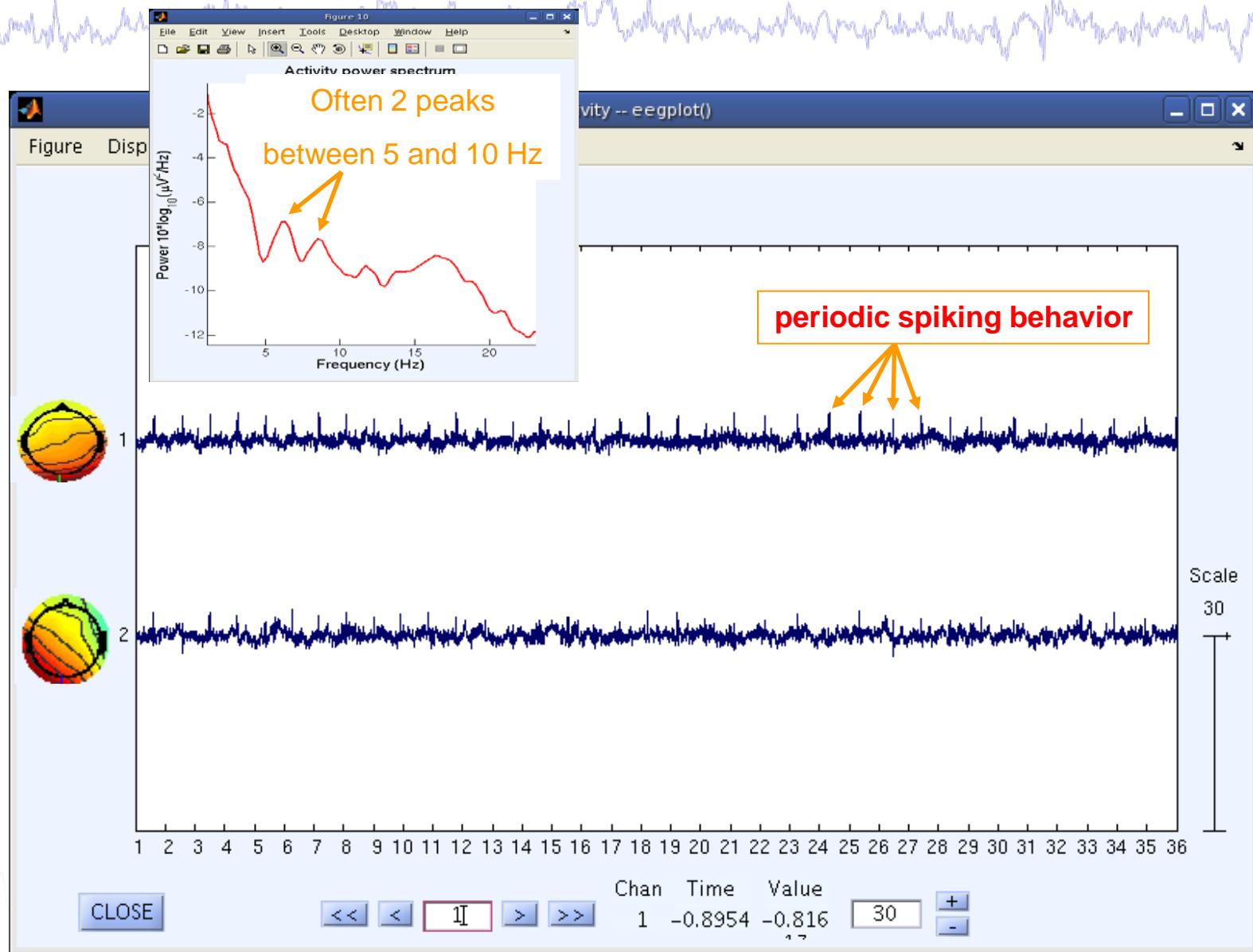
Bad  
channels







# Pulse artifacts



# Artifact rejection and running ICA



## Task 1

Reject noisy data

## Task 2

Run ICA

## Task 3

Plot components

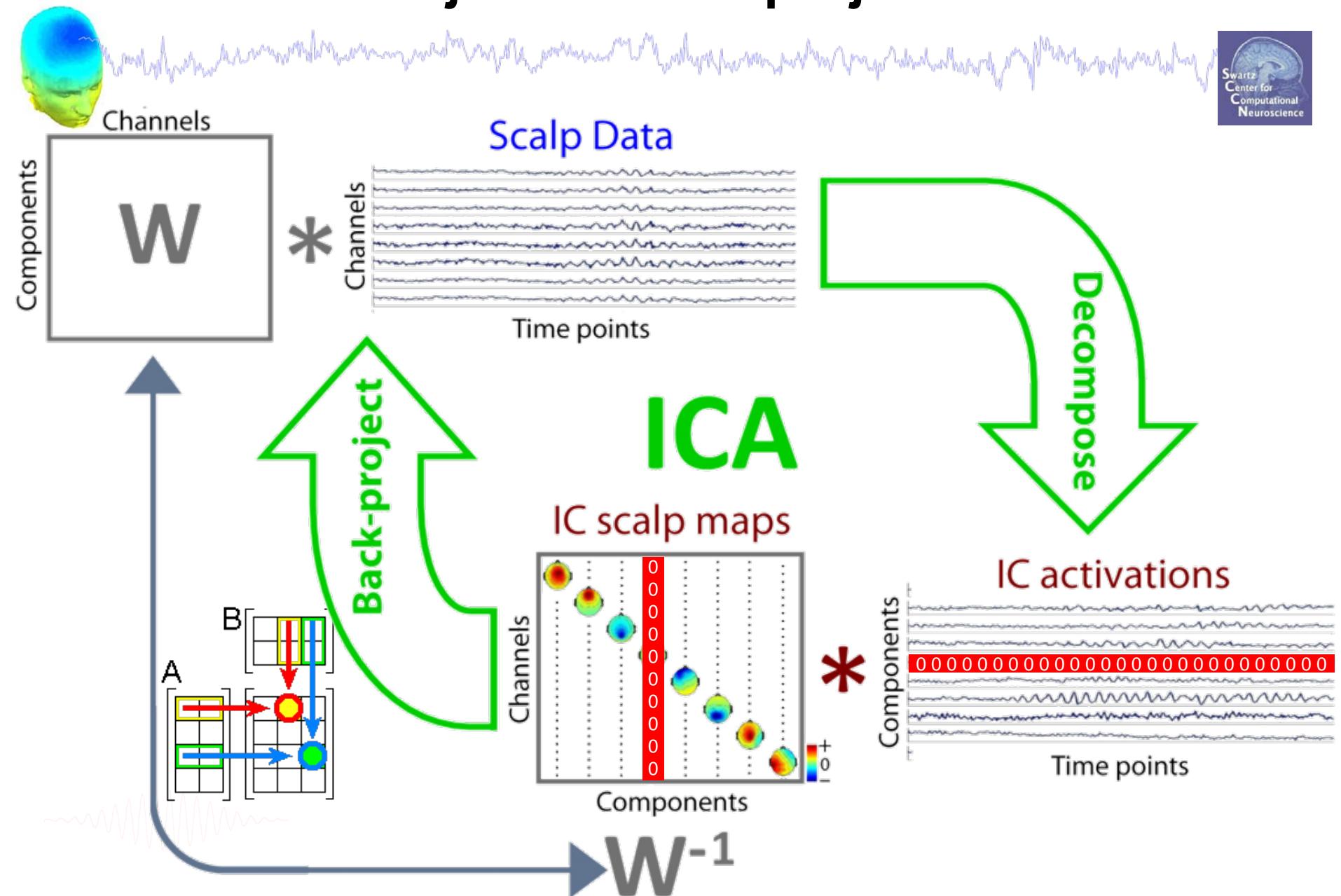
## Task 4

Remove components  
(i.e. back-projection)

## Exercise...

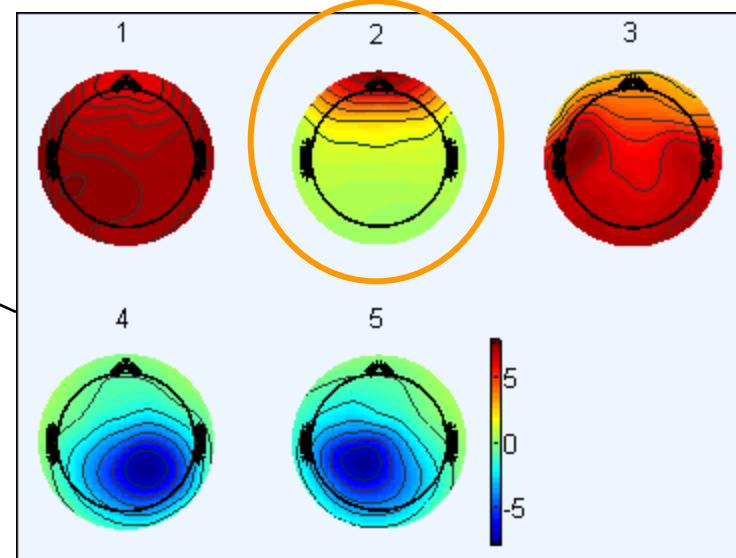
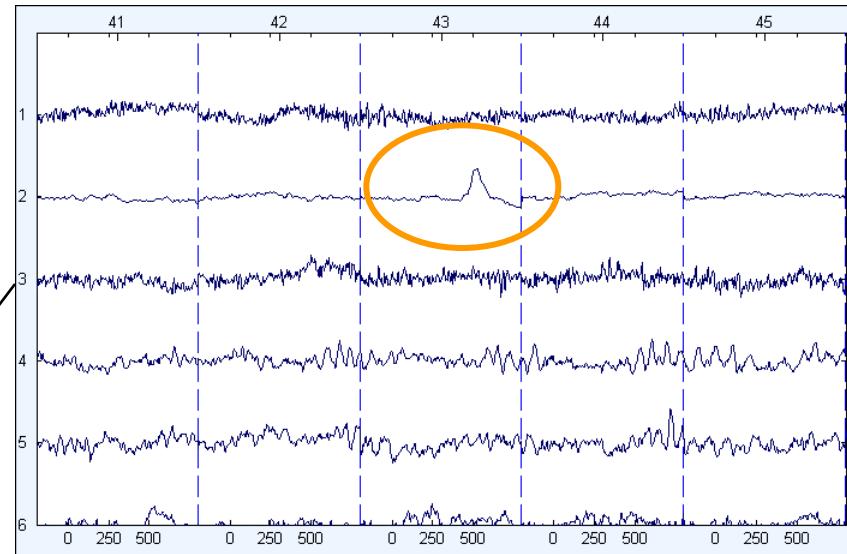
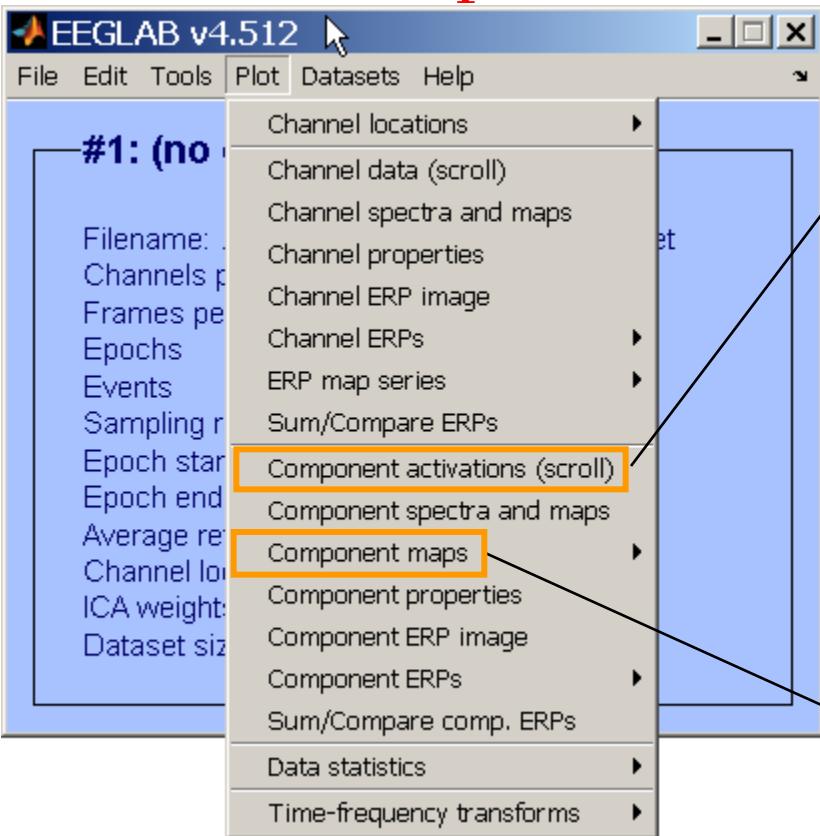


# IC rejection/back-projection

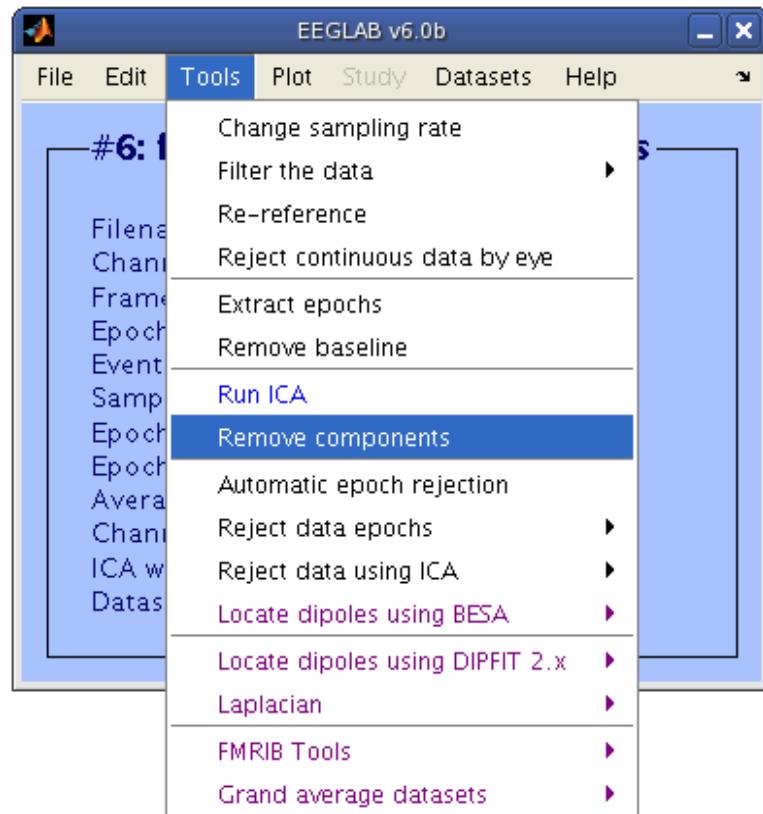
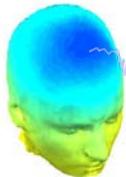


# Eye blink correction

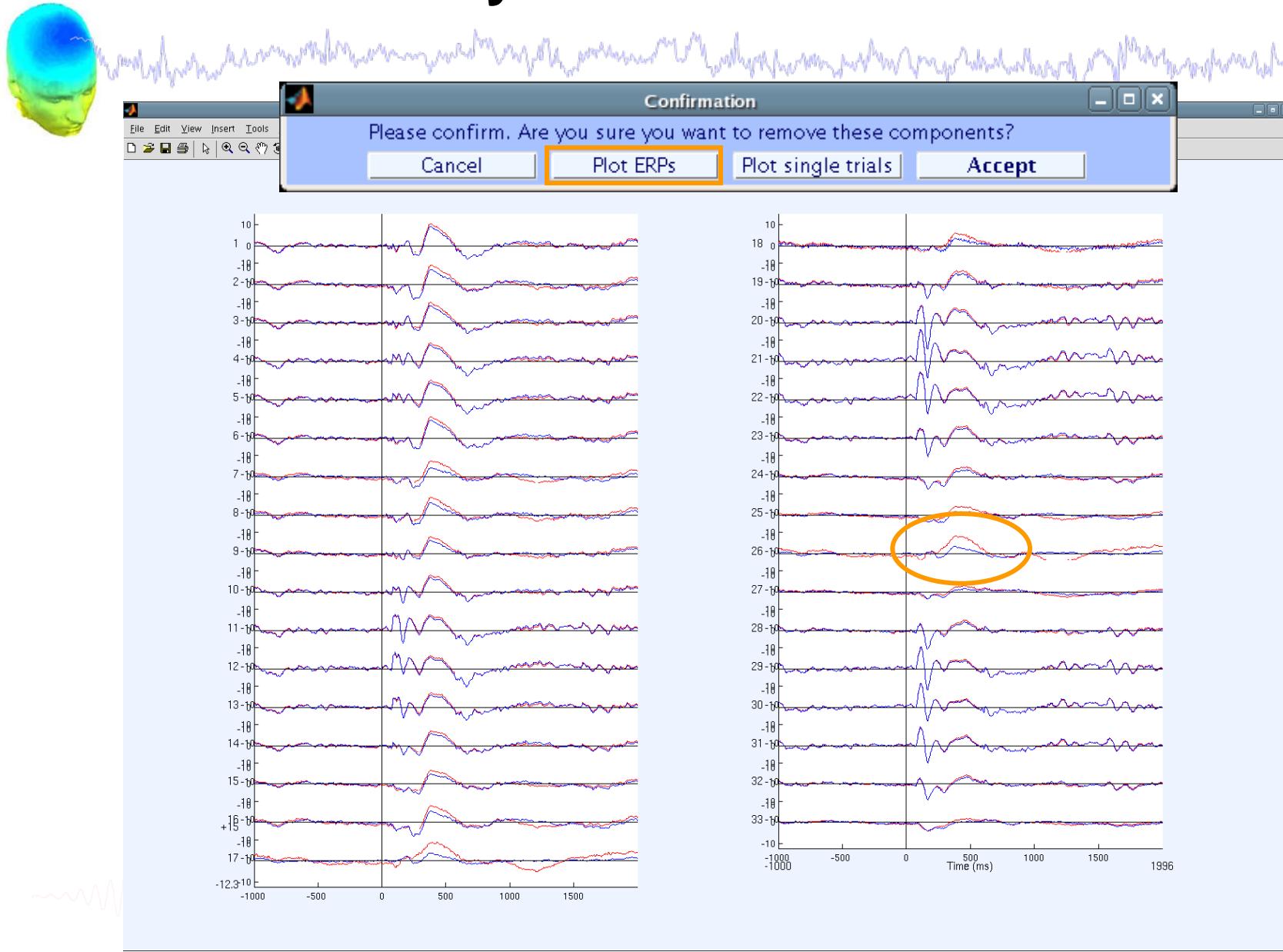
Identify eye-blink components:



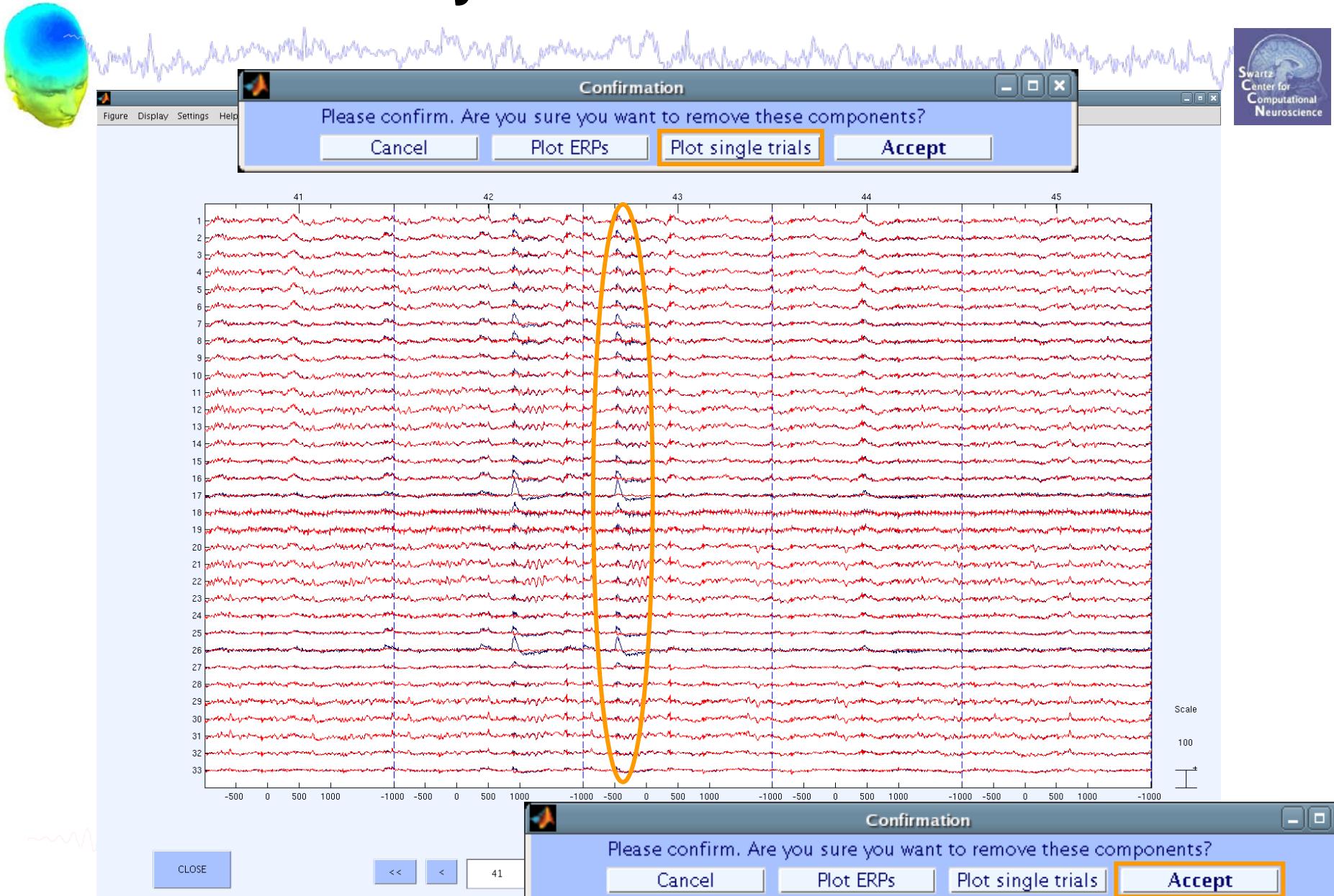
# Eye blink correction



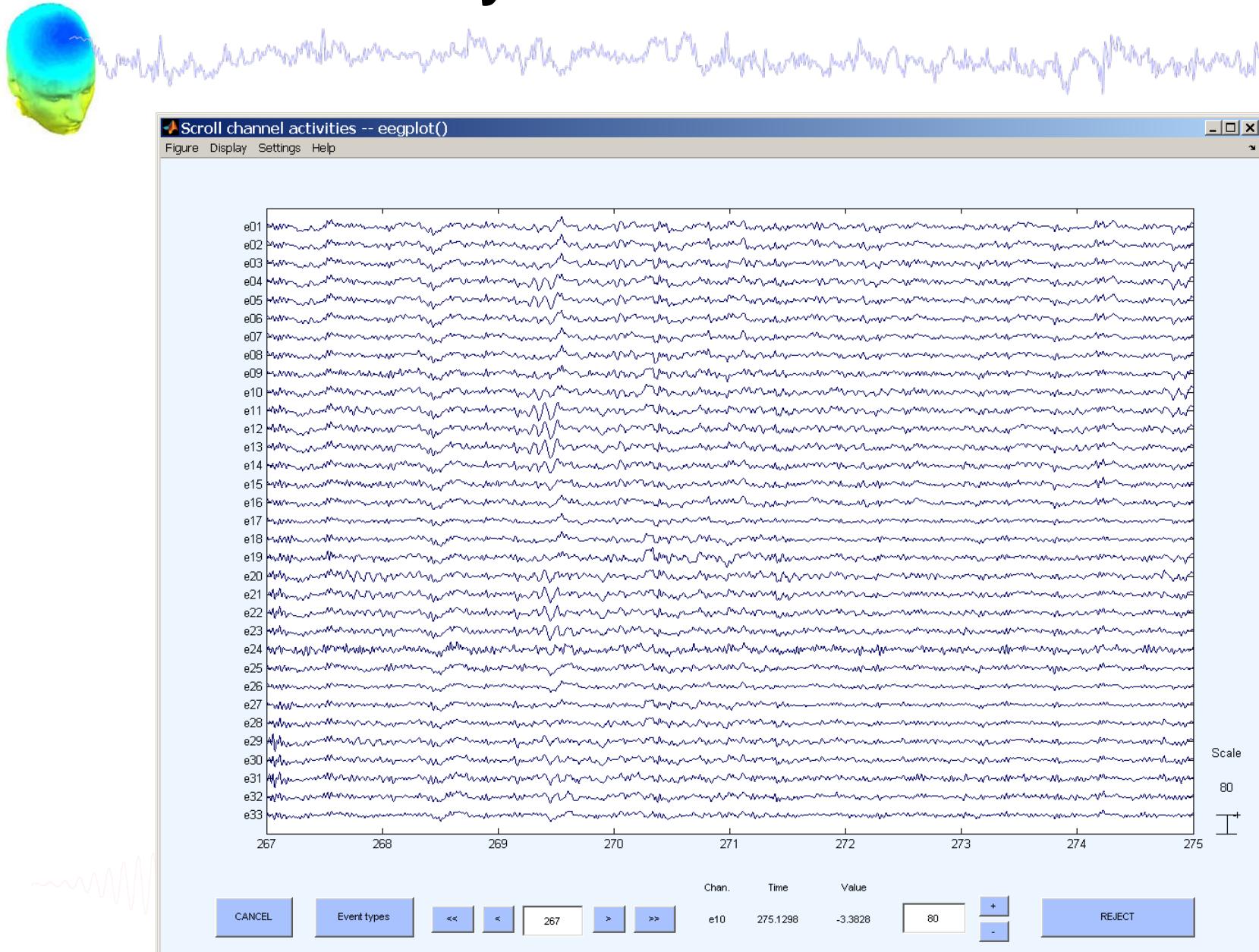
# Eye blink correction



# Eye blink correction



# Eye blink correction



# Exercise



- **ALL**

- Load stern.set or stern\_small.set
- Epoch the data on memorize and ignore letters
- From Reject data epochs->All methods menu
- Scroll the data and perform visual rejection
- Try other rejection protocols and compare
- Explore channel probability and abnormal distribution plots
- Find and identify artifact ICs
- How can you be sure that an IC is artifact?
- Remove a component from the EEG data (do not save this way!). Alternatively, try KEEPING just one component. What does the EEG.data scroll look like?

