

EEGLAB Tutorial In MATLAB

Armin Abdollahi

Signal Processing Teaching Assistant
Islamic Azad University, North Tehran Branch

Fall 2023



Introduction to EEG Signal and EEGLAB ToolBox

- EEG signals are generated by ionic currents in cortical neurons. Electroencephalography (EEG) is a method that measures the electrical activity of the brain. It is widely used in clinical and research settings to study brain function and diagnose neurological disorders.
- EEGLAB is an open source tool for processing EEG, MEG and other related electrophysiological data. It includes independent component analysis (ICA), time/frequency analysis, removal of several types of non-brain artifacts from EEG data, and several other modes.
- EEGLAB's graphical interface has a more user-friendly approach, but to fully utilize EEGLAB's potential, you must have a basic understanding of the MATLAB programming language.

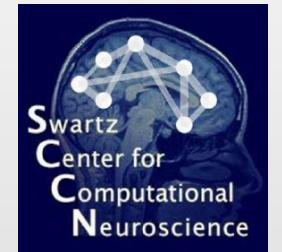
Software for analyzing EEG

MATLAB + EEGLAB + ERPLAB

MATLAB: A proprietary computer language that specializes in matrix algebra.



EEGLAB: A free, open source toolbox for EEG analysis developed by the Swartz Center at UC San Diego



ERPLAB: A free, open source plugin for EEGLAB developed by Steve Luck's lab at UC Davis.



Opinion: If you only want to do ERPs, this is probably the best software solution. EEGLAB and ERPLAB are mature toolboxes, with tons of documentation, tutorials, discussion boards, etc. They can be run either through a GUI or through scripting. Steve Luck developed ERPLAB to implement his ideas about how best to do ERP research, so it works well with his textbook. EEGLAB is also great for ICA, but not great for time-frequency analysis.

Software for analyzing EEG

MATLAB + FieldTrip

MATLAB: A proprietary computer language that specializes in matrix algebra.



FieldTrip: A free, open source toolbox for EEG analysis developed by the Donders Institute in Nijmegen



Opinion: FieldTrip is the best option if you want to do time-frequency analysis. It is also completely fine for ERPs. But it does not have a GUI, so you have to be comfortable with scripting (it is a set of Matlab functions that you can call to perform different EEG analyses)

Software for analyzing EEG

Python + MNE-Python

Python: A free, open-source computer language

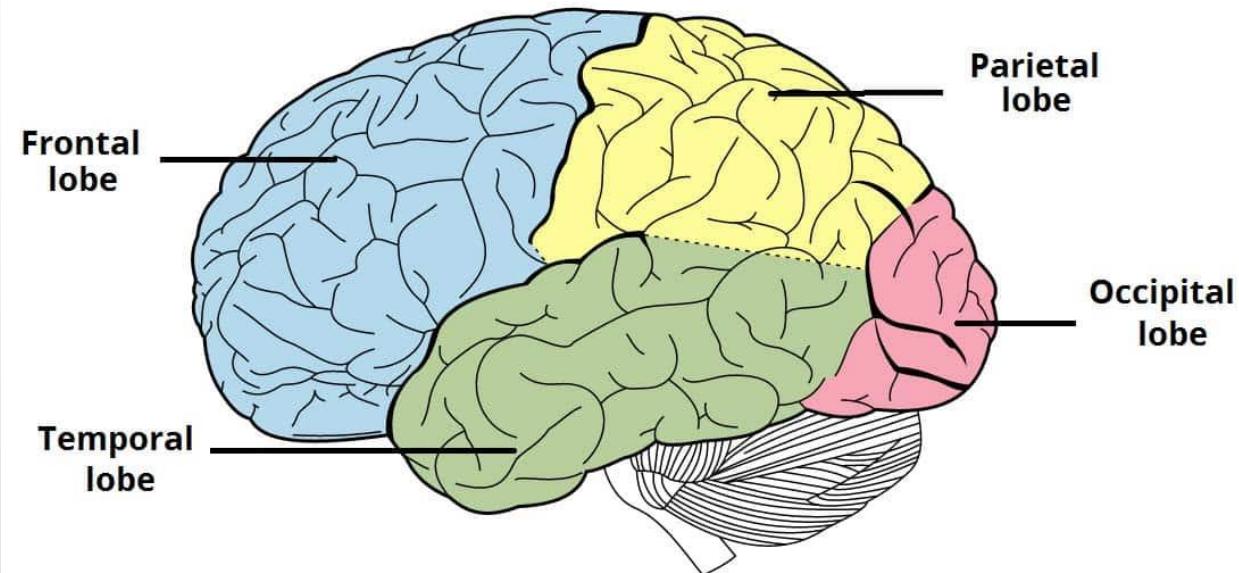
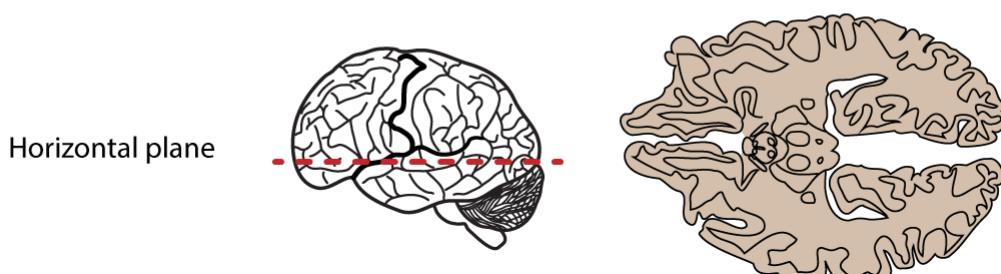
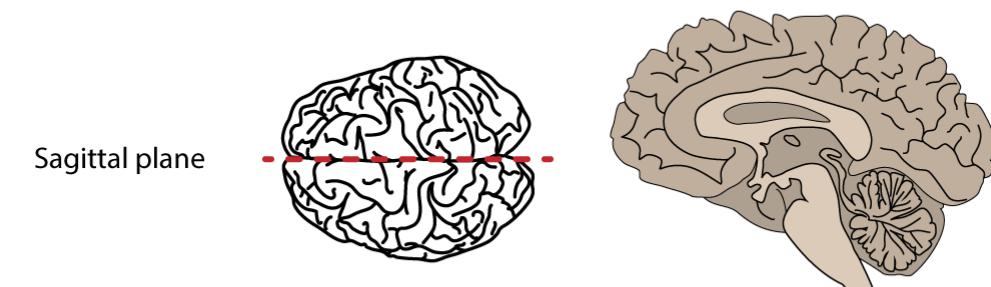
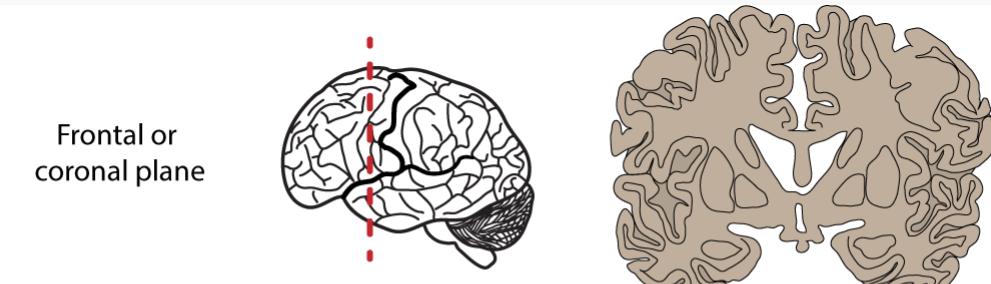


MNE: A free, open source toolbox for EEG analysis developed by a community of labs



Opinion: I don't have much experience with MNE-python. My impression is that it is completely adequate for ERPs and time-frequency, and that it excels at source localization. I think it may become an interesting option as Python slowly takes over market share from Matlab.

Brain Divisions



Frontal Lobe: It is located in the front of the head and is responsible for attention, attention and perception.

Temporal Lobe: It is located above the ear on both sides and is responsible for hearing.

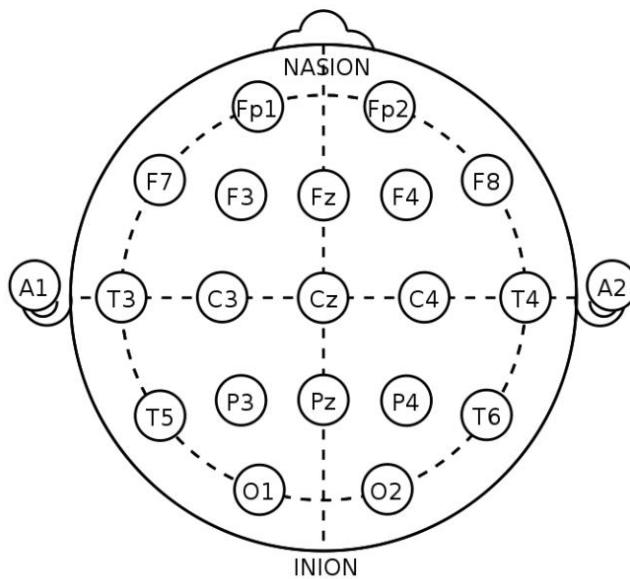
Occipital Lobe: It is located at the back of the head, above the neck and is responsible for vision.

Parietal Lobe: Above the head is the back of the head and is responsible for controlling our movements.

Naming of EEG Electrodes

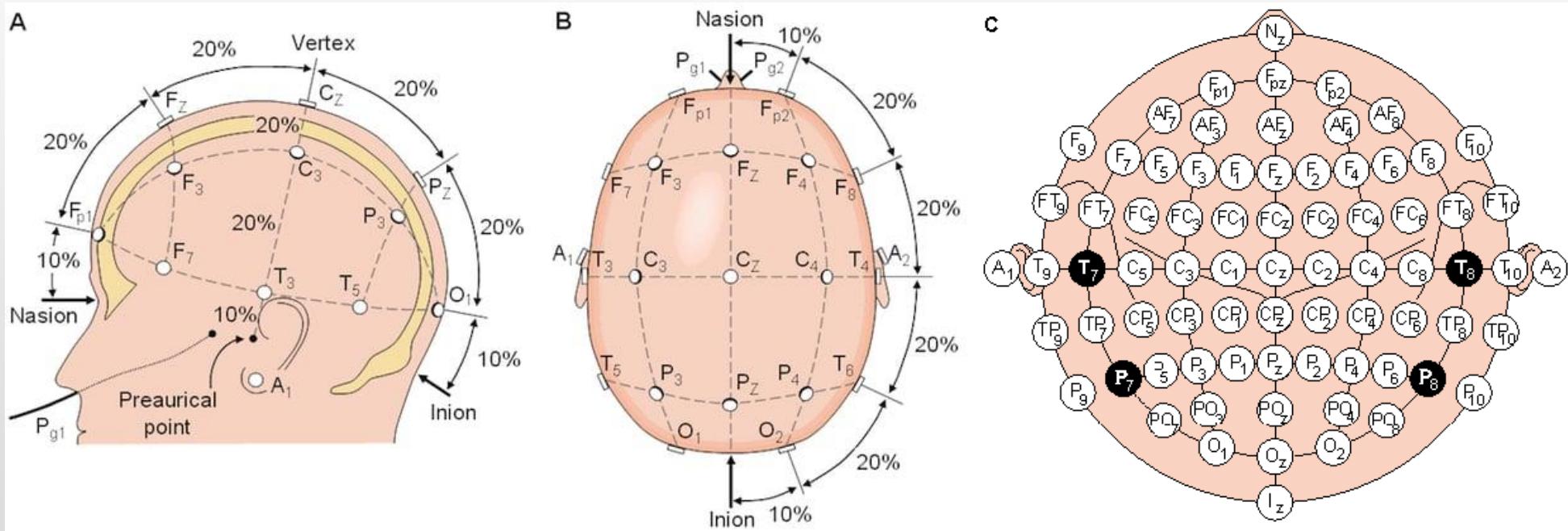


Brain Products Caps

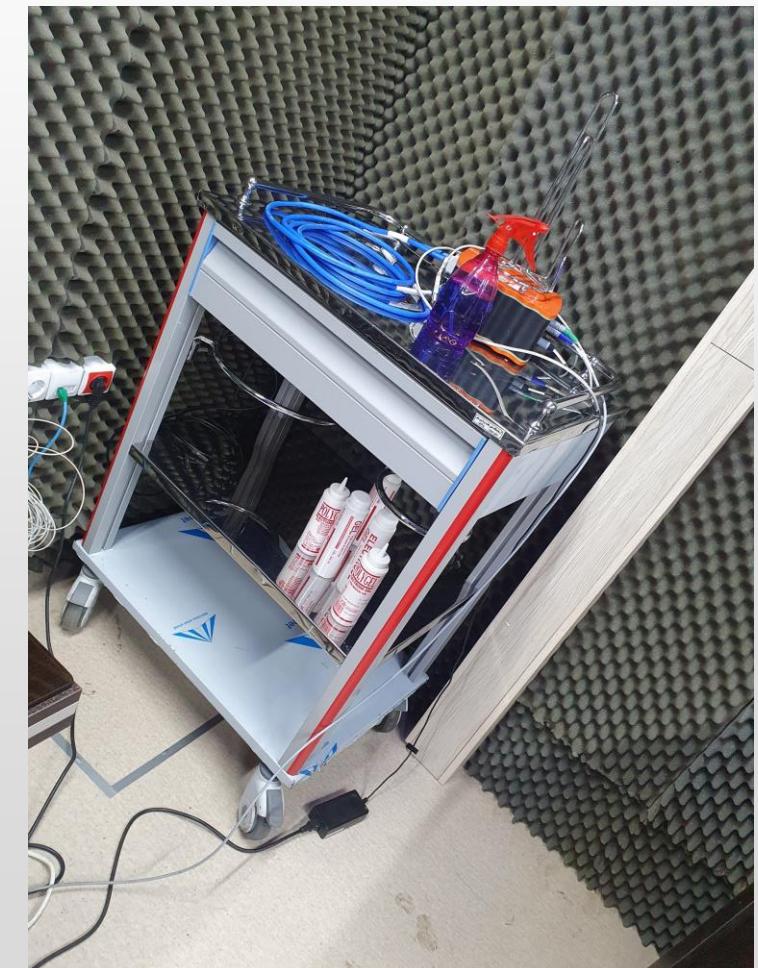


EEG electrodes:
F: Frontal
C: Central
T: Temporal
P: Parietal
O: Occipital

EEG Standards



EEG Recording



Transcranial Magnetic Stimulation (TMS)



Download and Install EEGLAB

Where can we download EEGLAB?

<https://sccn.ucsd.edu/eeglab/downloadtoolbox.php/download.php>

Size: 90 MB

How to install EEGLAB?

1. Unzip the EEGLAB zip file in the folder of your choice
2. Start MATLAB
3. Change the MATLAB path to the EEGLAB folder you have just uncompressed
4. Type "eeglab" and press enter on the MATLAB prompt





Workspace

Name	Value
ALLCOM	1x1 cell
ALLEEG	[]
CURRENTS...	0
CURRENTS...	0
EEG	1x1 struct
globalvars	8x1 cell
LASTCOM	[ALLEEG EEG ...]
PLUGINLIST	1x9 struct
STUDY	[]
tmpEEG	1x1 struct

Command Window

```
>> eeglab
```

Some menus items hidden. Use Preference menu to show them all.
eeglab: options file is C:\Users\ASUS\eeg_options.m
Retrieving plugin versions from server...
Retrieving download statistics...
EEGLAB: adding "Biosig" v3.8.1 to the path
EEGLAB: adding "Fileio" v20230402 to the path
EEGLAB: adding "ICLabel" v1.4 (see >> help eeg
EEGLAB: adding "MFMatlabIO" v4.1 (see >> help eeg
EEGLAB: adding "bva-io" v1.71 (see >> help eeg
EEGLAB: adding "clean_rawdata" v2.8 (see >> he
EEGLAB: adding "dipfit" v5.0 (see >> help eegp
EEGLAB: adding "firfilt" v2.7.1 (see >> help e
EEGLAB: adding "neuroscanno" v1.6 (see >> help
You are using the latest version of EEGLAB.

fx>>

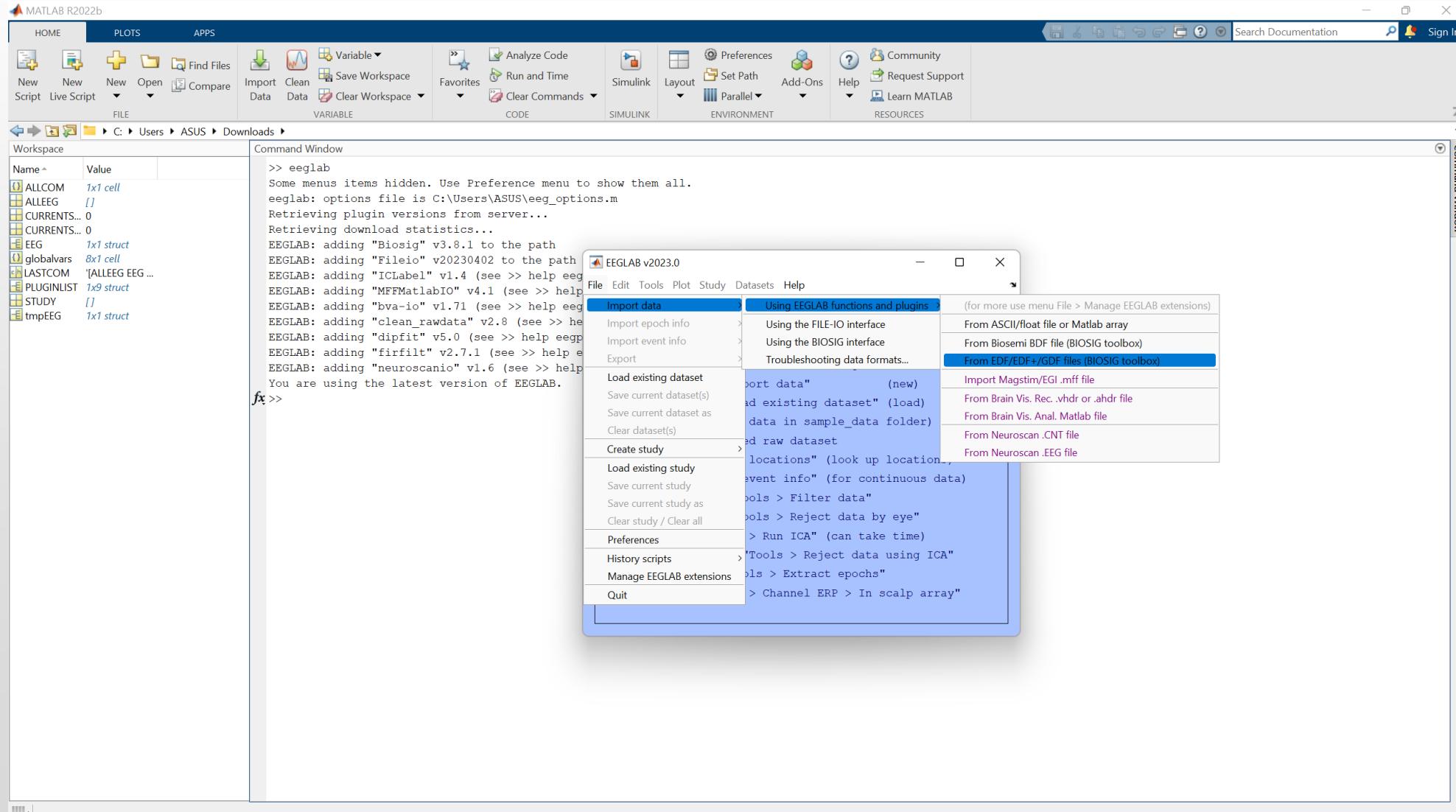
EEGLAB v2023.0

No current dataset

Suggested steps to get started

- Create a new or load an existing dataset:
Use "File > Import data" (new)
Or "File > Load existing dataset" (load)
(find tutorial data in sample_data folder)
- If newly imported raw dataset
"Edit > Channel locations" (look up locations)
"File > Import event info" (for continuous data)
- Filter data: "Tools > Filter data"
- Reject data: "Tools > Reject data by eye"
- Run ICA: "Tools > Run ICA" (can take time)
- Reject by ICA: "Tools > Reject data using ICA"
- Epoch data: "Tools > Extract epochs"
- Plot ERP: "Plot > Channel ERP > In scalp array"

Import the signal to EEGLAB





Workspace

Name	Value
ALLCOM	1x1 cell
ALLEEG	[]
CURRENTS...	0
CURRENTS...	0
EEG	1x1 struct
globalvars	8x1 cell
LASTCOM	"
PLUGINLIST	1x9 struct
STUDY	[]
tmpEEG	1x1 struct

Command Window

```
>> eeglab
Some menus items hidden. Use Preference menu to show them all.
eeglab: options file is C:\Users\ASUS\eeg_options.m
Retrieving plugin versions from server...
Retrieving download statistics...
EEGLAB: adding "Biosig" v3.8.1 to the path
EEGLAB: adding "Fileio" v20230402 to the path
EEGLAB: adding "ICLabel" v1.4 (see >> help eeg
EEGLAB: adding "MFMatlabIO" v4.1 (see >> help eeg
EEGLAB: adding "bva-io" v1.71 (see >> help eeg
EEGLAB: adding "clean_rawdata" v2.8 (see >> he
EEGLAB: adding "dipfit" v5.0 (see >> help eeg
EEGLAB: adding "firfilt" v2.7.1 (see >> help e
EEGLAB: adding "neuroscanno" v1.6 (see >> help
You are using the latest version of EEGLAB.
```

fx >>

EEGLAB v2023.0

Choose a data file -- pop_biosig()

This PC > This PC > Desktop >

Organize New folder

This PC

- Desktop
- Documents
- Downloads
- Music
- Pictures
- Videos
- Local Disk (C:)

Dataset Master PN05-3.edf Standard-10-10-Cap47.locs

File name: PN05-3.edf

All Files

Open Cancel

Document1 - Word

Armin Abdollahi

File Home Insert Draw Design Layout References Mailings Review View Help Foxit PDF Tell me what you want to do

Cut Copy Format Painter

Paste

Font Paragraph Styles

Clipboard

Find Replace Select Add-ins

Editing Add-ins

Number	labels	theta	radius	X	Y	Z	sph_theta
	sph_phi	sph_radius					
1	FPZ	0	0.511 0.999 -0	-0.0349	-0	-2	1
2	FZ	0	0.256 0.719 -0	0.695 -0	44	1	
3	Cz	90	0 3.75e-33	-6.12e-17	1	-90	90
4	PZ	180	0.256 -0.719	-8.81e-17	0.695 -180	44	1
5	C3	-90	0.256 4.4e-17	0.719 0.695	90 44	1	
6	T3	-90	0.511 6.12e-17	0.999 -0.0349	90	-2	1
7	C4	90	0.256 4.4e-17	-0.719	0.695 -90	44	1
8	T4	90	0.511 6.12e-17	-0.999	-0.0349	-90	-2
9	FP1	-18	0.511 0.95 0.309 -0.0349	18	-2	1	
10	FP2	18	0.511 0.95 -0.309 -0.0349	-18	-2	1	
11	F3	-39	0.333 0.673 0.545 0.5	39	30	1	
12	F4	39	0.333 0.673 -0.545 0.5	-39	30	1	
13	F7	-54	0.511 0.587 0.809 -0.0349	54	-2	1	
14	F8	54	0.511 0.587 -0.809 -0.0349	-54	-2	1	
15	P3	-141	0.333 -0.673 0.545 0.5	141	30	1	
16	P4	141	0.333 -0.673 -0.545 0.5	-141	30	1	
17	T5	-126	0.511 -0.587 0.809 -0.0349	126	-2	1	
18	T6	126	0.511 -0.587 -0.809 -0.0349	-126	-2	1	
19	O1	-162	0.511 -0.95 0.309 -0.0349	162	-2	1	
20	O2	162	0.511 -0.95 -0.309 -0.0349	-162	-2	1	

Seizures-list-PN05 X +

File Edit View

PN05

Data Sampling Rate: 512 Hz

Channels in EDF files:

Channel 1: Fp1
Channel 2: F3
Channel 3: C3
Channel 4: P3
Channel 5: 1
Channel 6: F7
Channel 7: T3
Channel 8: T5
Channel 9: Fc1
Channel 10: Fc5
Channel 11: Cp1
Channel 12: Cp5
Channel 13: F9
Channel 14: Fz
Channel 15: Cz
Channel 16: Pz
Channel 17: F4
Channel 18: C4
Channel 19: P4
Channel 20: O2
Channel 21: F8
Channel 22: T4
Channel 23: T6
Channel 24: Fc2
Channel 25: Fc6
Channel 26: Cp2
Channel 27: Cp6
Channel 28: F10
Channel 32: EKG 1
Channel 33: EKG 2
Channel 34: Fp2

Seizure n 2:

File name: PN05-2.edf
Registration start time: 06.46.02
Registration end time: 09.19.47
Seizure start time: 08.45.25
Seizure end time: 08.46.00

Ln 1, Col 1

Seizures-list-PN05 X +

File Edit View

Channel 11: Cp1
Channel 12: Cp5
Channel 13: F9
Channel 14: Fz
Channel 15: Cz
Channel 16: Pz
Channel 17: F4
Channel 18: C4
Channel 19: P4
Channel 20: O2
Channel 21: F8
Channel 22: T4
Channel 23: T6
Channel 24: Fc2
Channel 25: Fc6
Channel 26: Cp2
Channel 27: Cp6
Channel 28: F10
Channel 32: EKG 1
Channel 33: EKG 2
Channel 34: Fp2

Seizure n 2:

File name: PN05-2.edf
Registration start time: 06.46.02
Registration end time: 09.19.47
Seizure start time: 08.45.25
Seizure end time: 08.46.00

Seizure n 3:

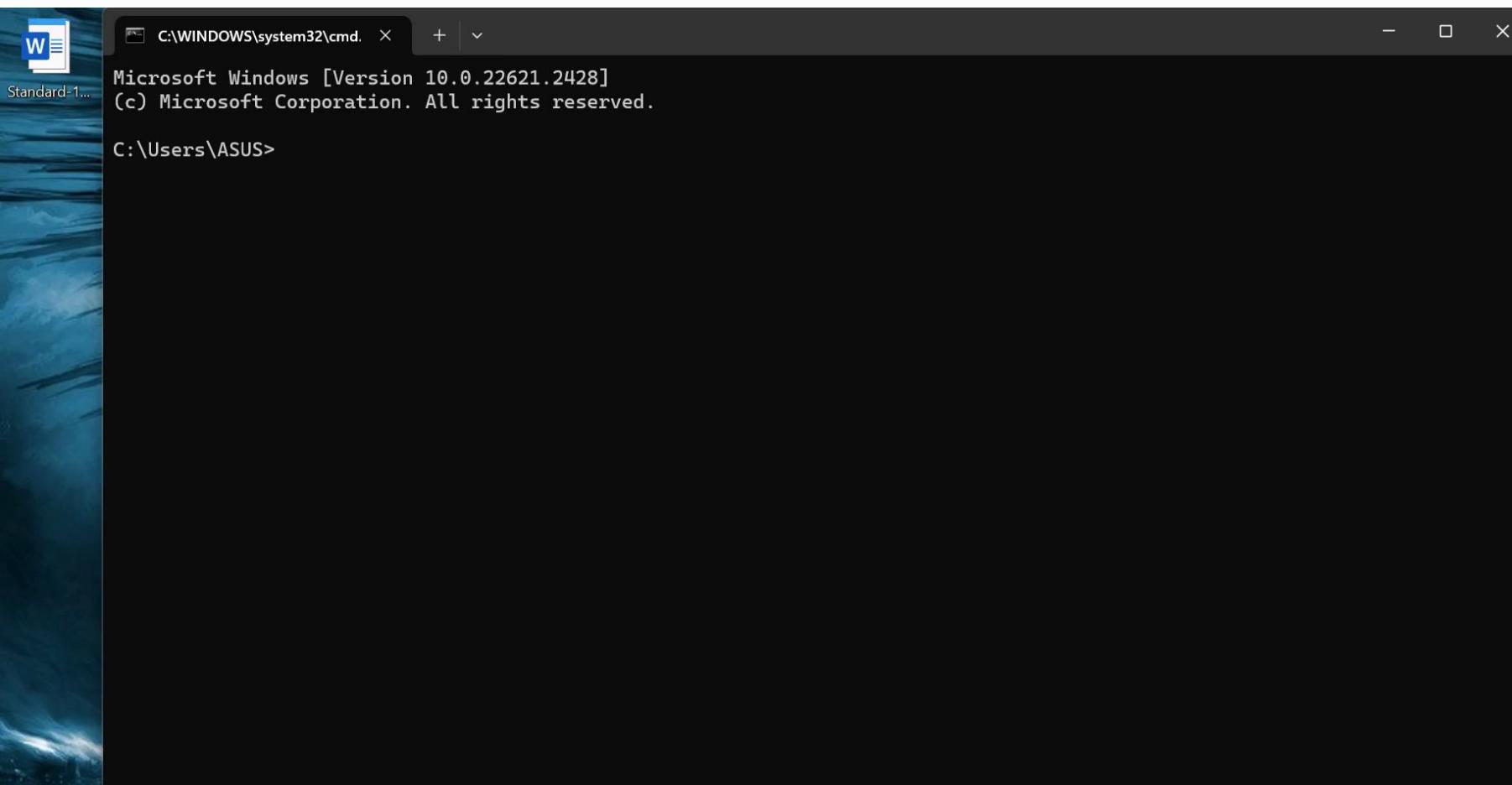
File name: PN05-3.edf
Registration start time: 06.01.23
Registration end time: 08.06.57
Seizure start time: 07.55.19
Seizure end time: 07.55.49

Seizure n 4:

File name: PN05-4.edf
Registration start time: 06.38.35
Registration end time: 08.00.23
Seizure start time: 07.38.43
Seizure end time: 07.39.22

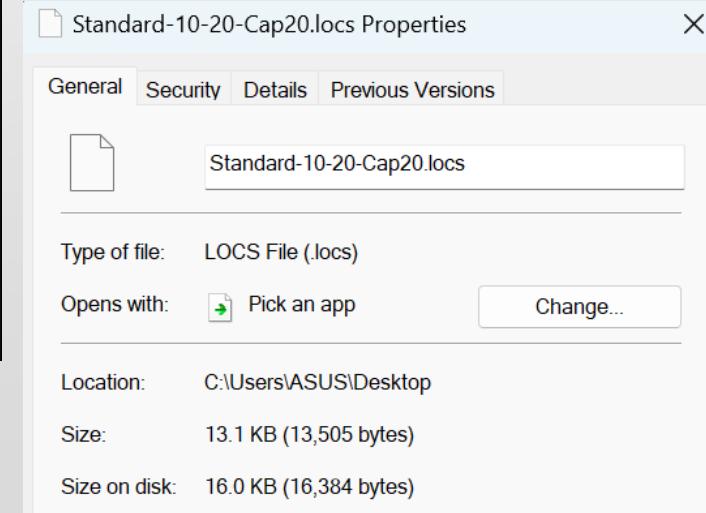
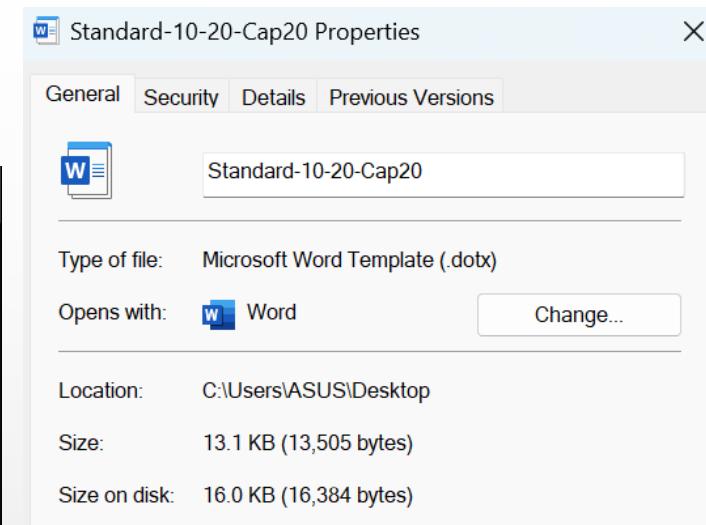
Ln 1, Col 1

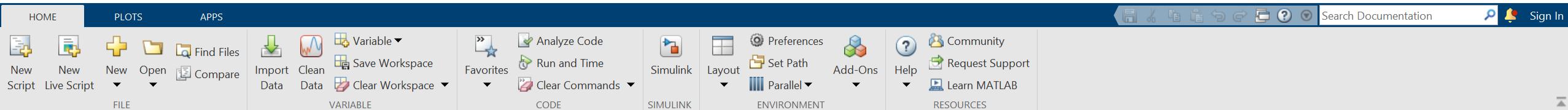
rename/ren [<drive>:] [<path>] <filename1> <filename2>



```
C:\WINDOWS\system32\cmd. x + v
Microsoft Windows [Version 10.0.22621.2428]
(c) Microsoft Corporation. All rights reserved.

C:\Users\ASUS>
```





Workspace

Name	Value
ALLCOM	1x3 cell
ALLEEG	1x1 struct
CURRENTS...	1
CURRENTS...	0
EEG	1x1 struct
globalvars	10x1 cell
LASTCOM	[ALLEEG EEG ...]
PLUGINLIST	1x9 struct
STUDY	[]
tmpEEG	1x1 struct

Command Window

```
>> eeglab
Some menus items hidden. Use Preference menu to show them all.
eeglab: options file is C:\Users\ASUS\eeg_options.m
Retrieving plugin versions from server...
Retrieving download statistics...
EEGLAB: adding "Biosig" v3.8.1 to the path
EEGLAB: adding "Fileio" v20230402 to the path
EEGLAB: adding "ICLabel" v1.4 (see >> help eeg
EEGLAB: adding "MFMatlabIO" v4.1 (see >> help
EEGLAB: adding "bva-io" v1.71 (see >> help eeg
EEGLAB: adding "clean_rawdata" v2.8 (see >> he
EEGLAB: adding "dipfit" v5.0 (see >> help eegp
EEGLAB: adding "firfilt" v2.7.1 (see >> help e
EEGLAB: adding "neuroscanio" v1.6 (see >> help
You are using the latest version of EEGLAB.
Reading data file header...
sopen mode is "OVERFLOWDETECTION:OFF"
Reading data in EDF format...
eeg_checkset note: upper time limit (xmax) adj
Detected/removing 'EEG' prefix from channel la
Extracting events from last EEG channel...
eeg_checkset warning: number of columns in dat
eeg_checkset note: creating the original event
Creating a new ALLEEG dataset 1
Done.
```

fx >>

EEGLAB v2023.0

#1: EDF file

Filename:	none
Channels per frame	36
Frames per epoch	3867648
Epochs	1
Events	5
Sampling rate (Hz)	512
Epoch start (sec)	0.000
Epoch end (sec)	7553.998
Reference	unknown
Channel locations	No (labels only)
ICA weights	No
Dataset size (Mb)	587.9



Workspace

Name	Value
ALLCOM	1x3 cell
ALLEEG	1x1 struct
CURRENTS...	1
CURRENTS...	0
EEG	1x1 struct
globalvars	10x1 cell
LASTCOM	'[ALLEEG EEG ...
PLUGINLIST	1x9 struct
STUDY	[]
tmpEEG	1x1 struct

Command Window

```
>> eeglab
Some menus items hidden. Use Preference menu to show them all.
eeglab: options file is C:\Users\ASUS\eeg_options.m
Retrieving plugin versions from server...
Retrieving download statistics...
EEGLAB: adding "Biosig" v3.8.1 to the path
EEGLAB: adding "Fileio" v20230402 to the path
EEGLAB: adding "ICLabel" v1.4 (see >> help eeg
EEGLAB: adding "MFMatlabIO" v4.1 (see >> help
EEGLAB: adding "bva-io" v1.71 (see >> help eeg
EEGLAB: adding "clean_rawdata" v2.8 (see >> he
EEGLAB: adding "dipfit" v5.0 (see >> help eegp
EEGLAB: adding "firfilt" v2.7.1 (see >> help e
EEGLAB: adding "neuroscanio" v1.6 (see >> help
You are using the latest version of EEGLAB.
Reading data file header...
sopen mode is "OVERFLOWDETECTION:OFF"
Reading data in EDF format...
eeg_checkset note: upper time limit (xmax) adj
Detected/removing 'EEG' prefix from channel la
Extracting events from last EEG channel...
eeg_checkset warning: number of columns in dat
eeg_checkset note: creating the original event
Creating a new ALLEEG dataset 1
Done.
```

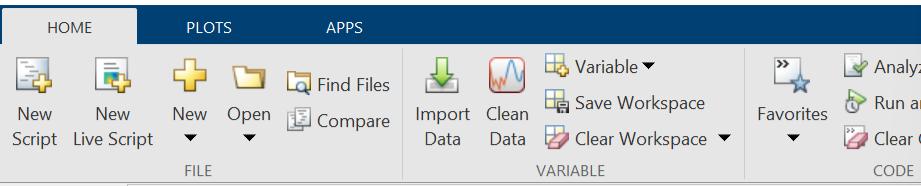
fx >>

EEGLAB v2023.0

File Edit Tools Plot Study Datasets Help

#1: E... Channel locations > Channel data (scroll) **Plot the signal**

Channel spectra and maps
Channel properties
Channel ERP image
Channel ERPs > 648
ERP map series
Channel time-frequency
Component activations (scroll)
Component spectra and maps
Component maps > 00
Component properties .998
Component ERP image
Component ERPs > own
Component time-frequency
ICA weights NO
Dataset size (Mb) 587.9



C: > Users > ASUS > Downloads >

Workspace		Command Window
Name	Value	
ALLCOM	1x4 cell	>> eeglab Some menus items hidden. Use Preference m...
ALLEEG	1x1 struct	eeglab: options file is C:\Users\ASUS\eed...
ans	[]	Retrieving plugin versions from server...
CURRENTS...	1	Retrieving download statistics...
CURRENTS...	0	EEGLAB: adding "Biosig" v3.8.1 to the pat...
EEG	1x1 struct	EEGLAB: adding "Fileio" v20230402 to the
globalv		>> hel (see >> help) 8 (see >> help) of EEGLAB
LASTCO		>> help (see >> help) of EEGLAB
PLUGIN		>> help (see >> help) of EEGLAB
STUDY		>> help (see >> help) of EEGLAB
tmpEEG		>> help (see >> help) of EEGLAB

EEGLAB v2023.0

File Edit Tools Plot Study Datasets Help

#1: EDF file

Filename: none

Channels per frame 36

Frames per epoch 3867648

Epochs 1

Events 5

Sampling rate (Hz) 512

Epoch start (sec) 0.000

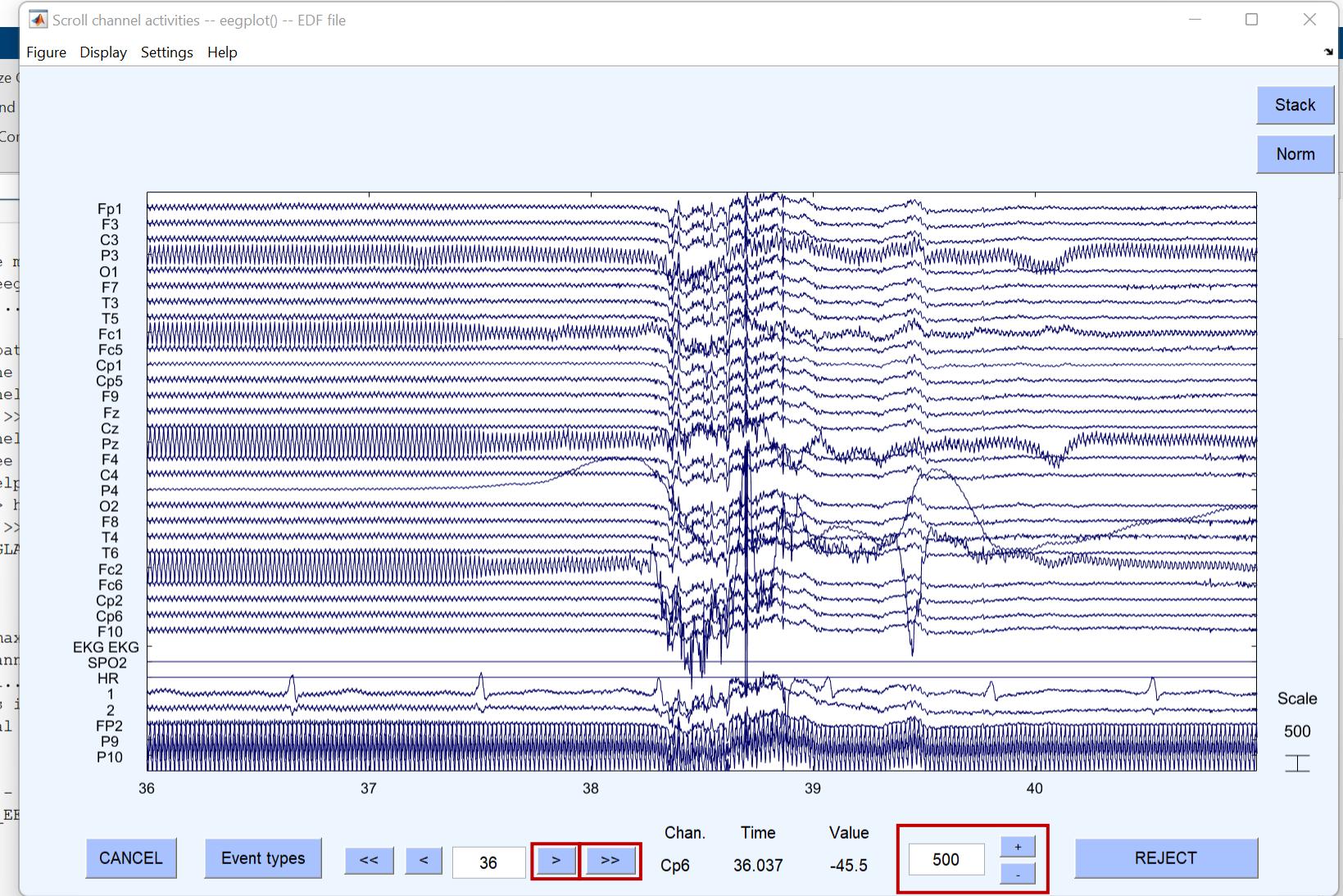
Epoch end (sec) 7553.998

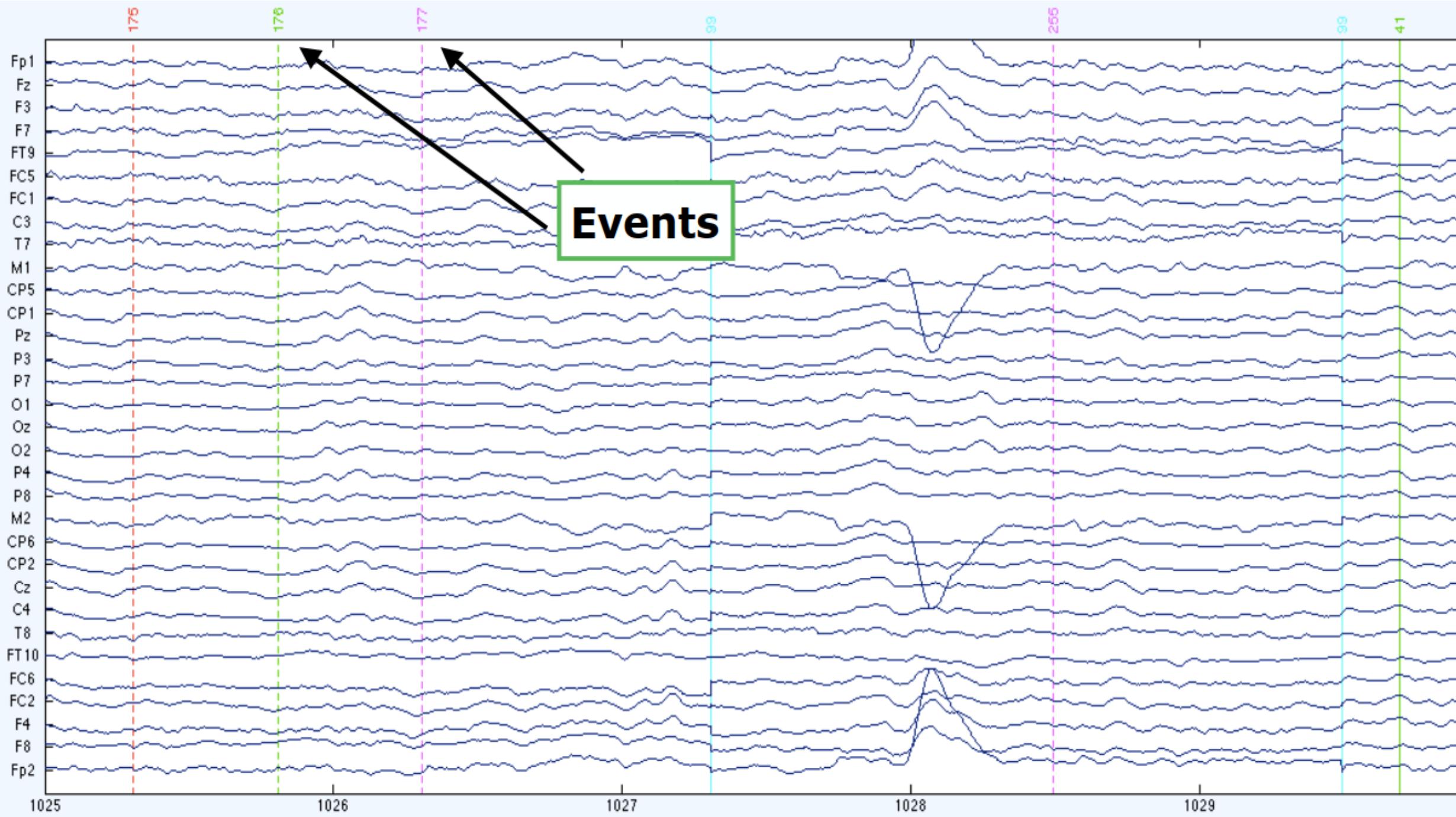
Reference unknown

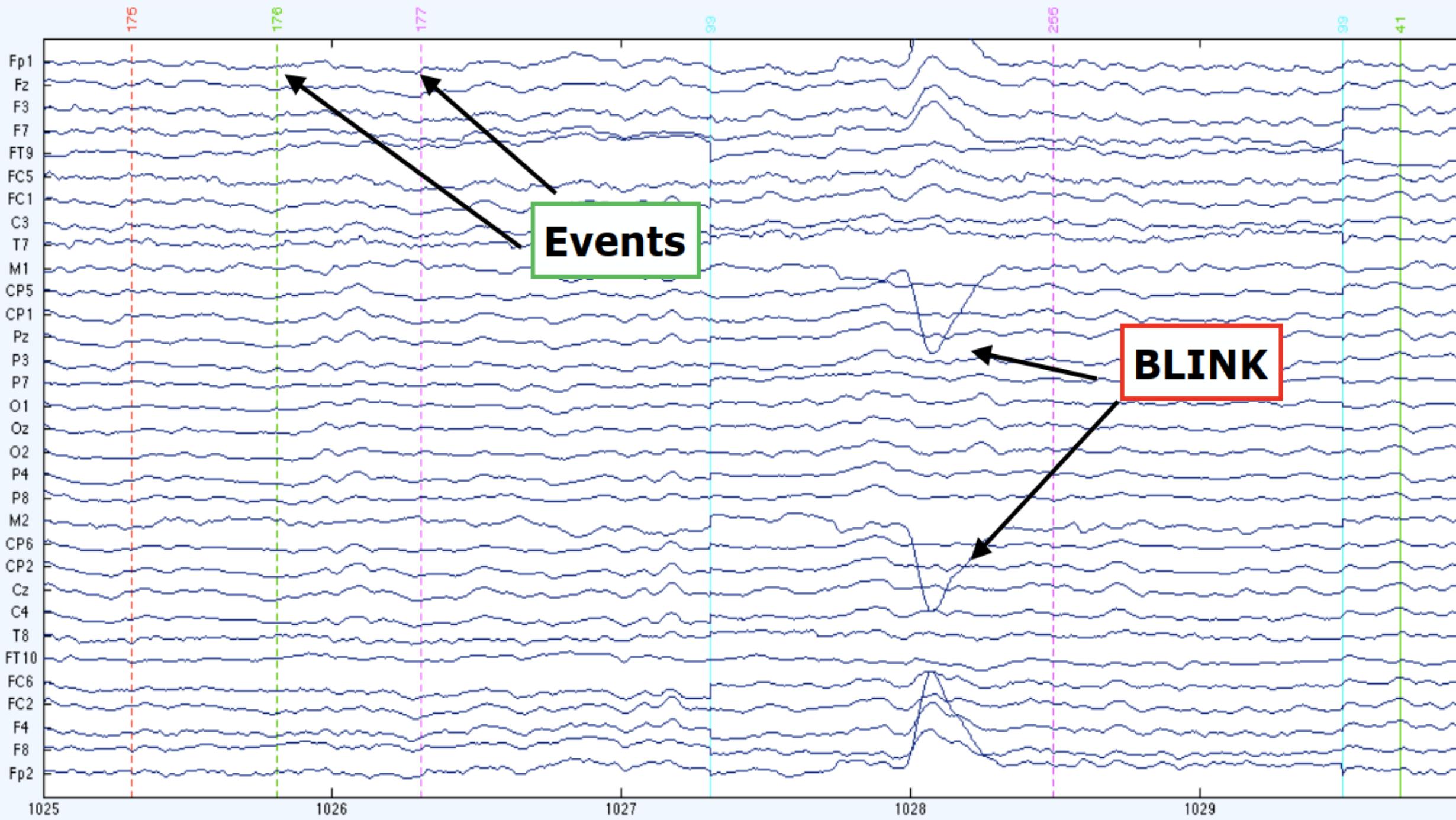
Channel locations No (labels only)

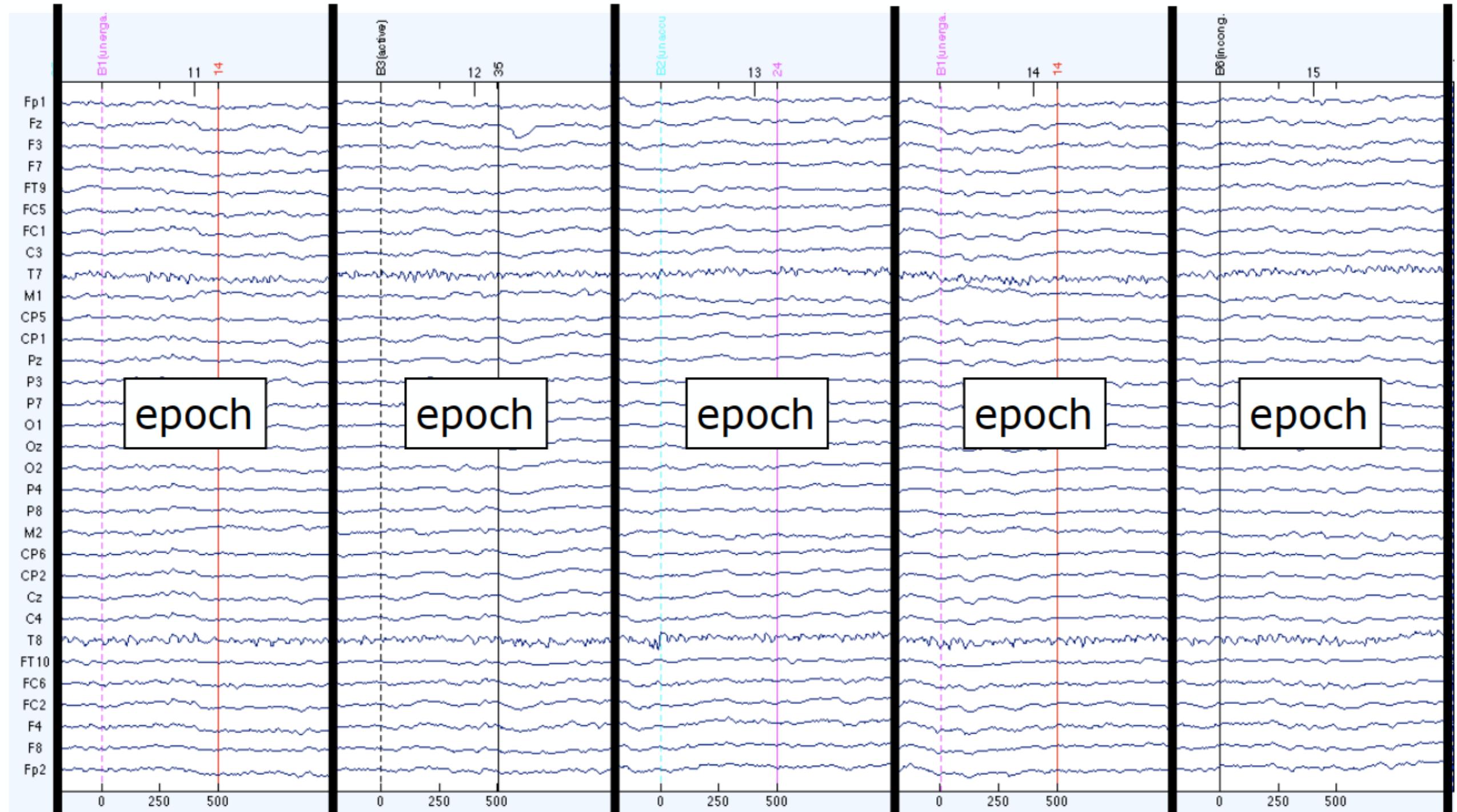
ICA weights No

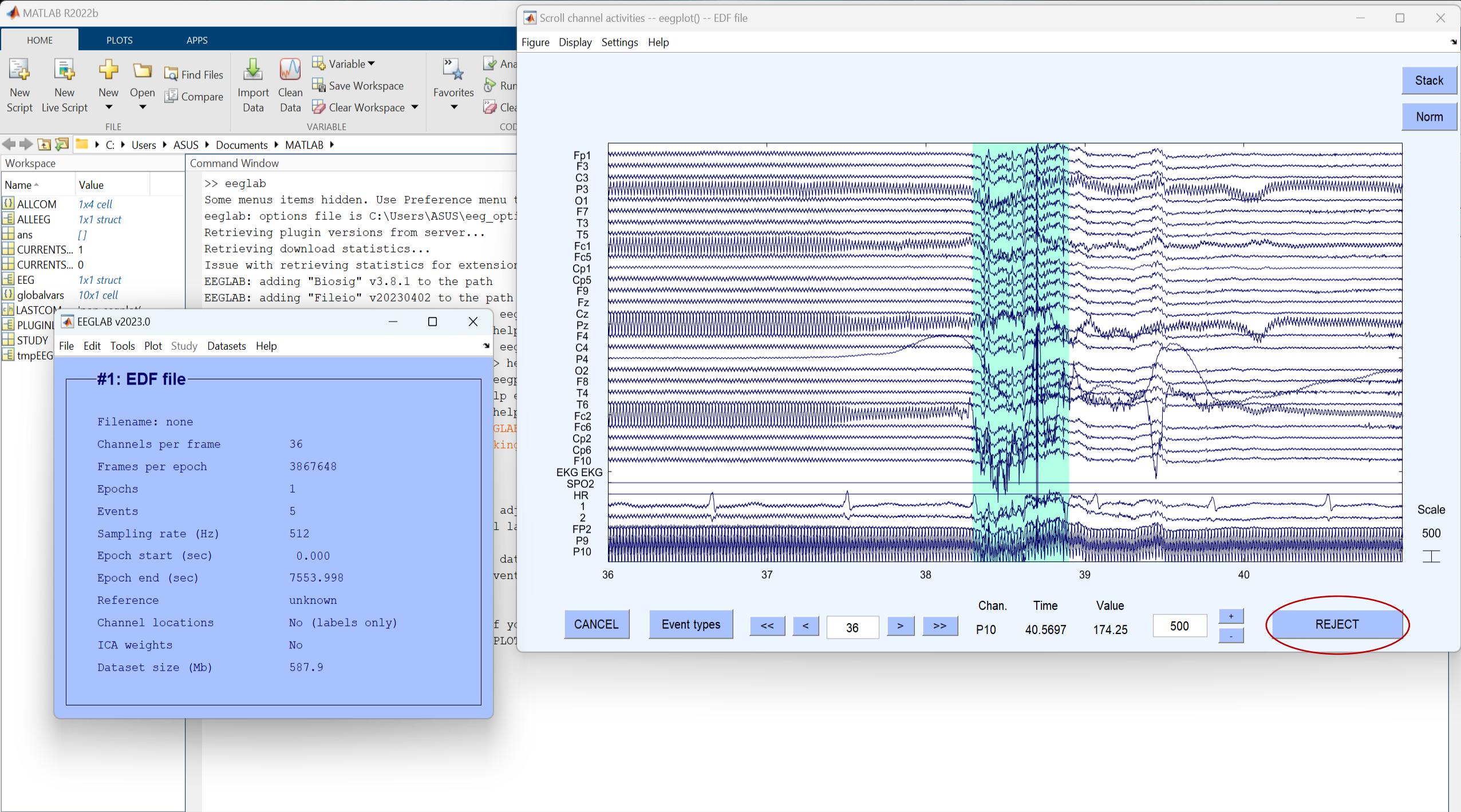
Dataset size (Mb) 587.9

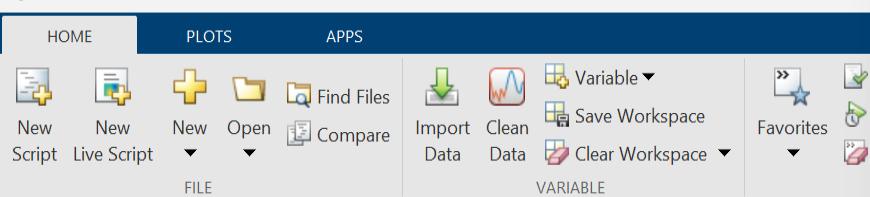








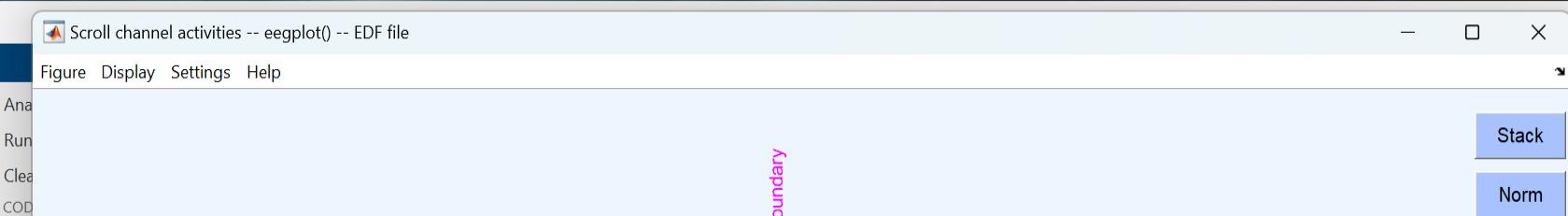




C:\Users\ASUS\Documents\MATLAB>

Workspace

Name	Value
ALLCOM	1x7 cell
ALLEG	1x2 struct
ans	[]
CURRENTS...	2
CURRENTS...	0
EEG	1x1 struct
globalvars	10x1 cell
LASTCOM	
PLUGINS	EEGLAB v2023.0
STUDY	
tmpEEG	
TMPREJ	



FILE

VARIABLE

CODE

CWD

HELP

PREFERENCES

ABOUT

QUIT

EXIT

HELP

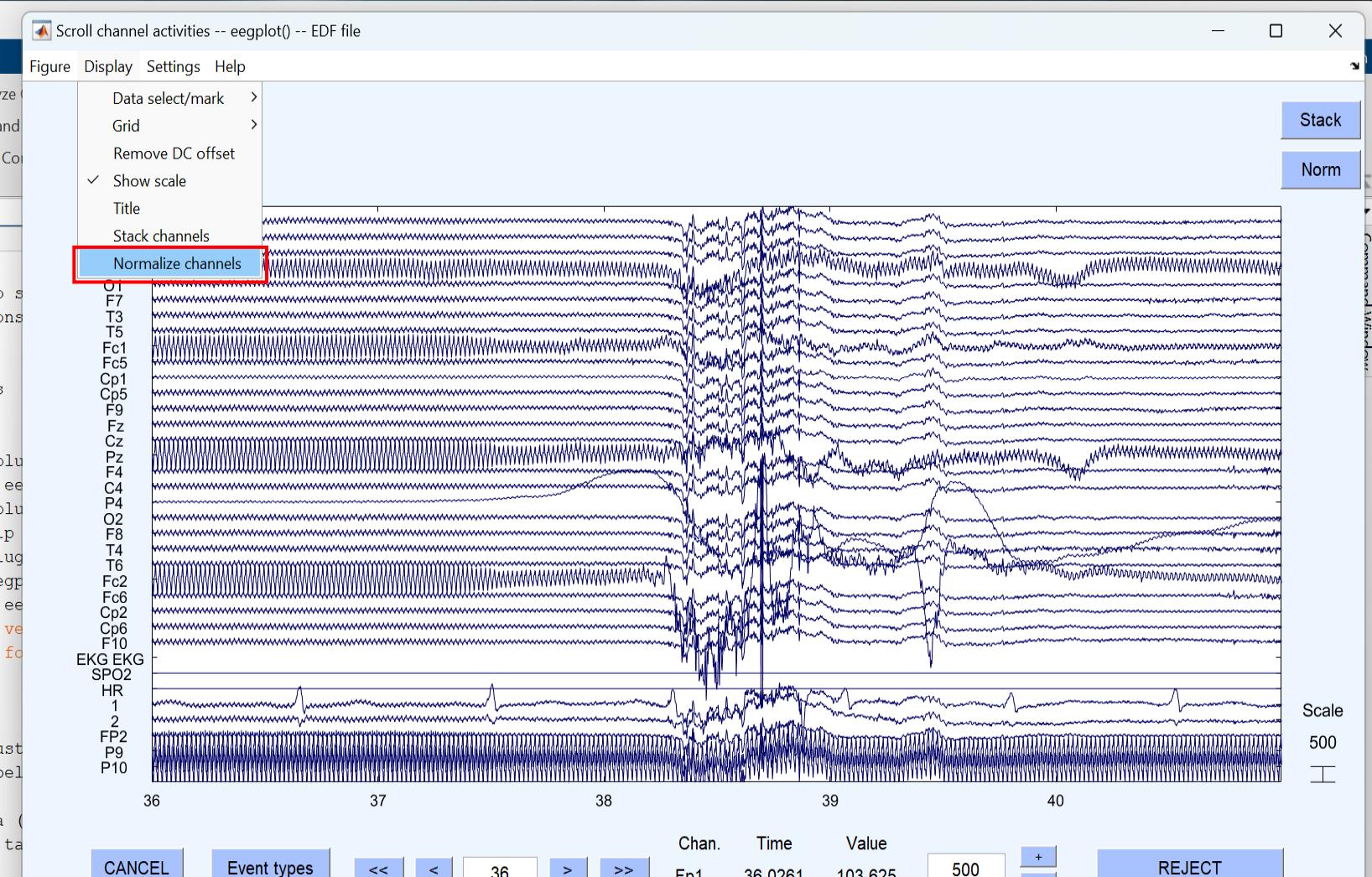
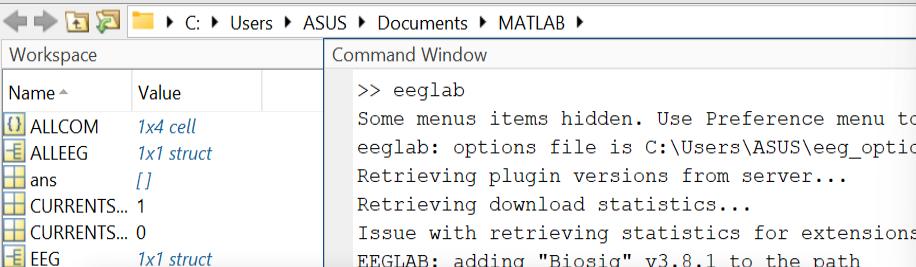
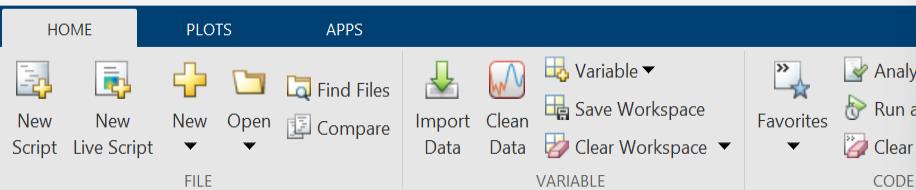
PREFERENCES

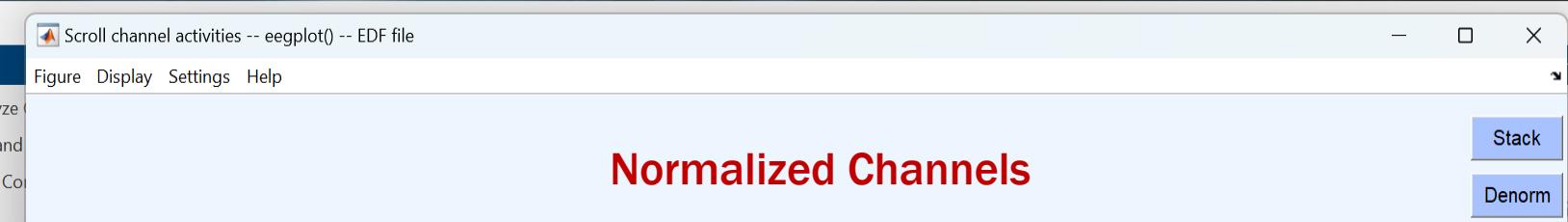
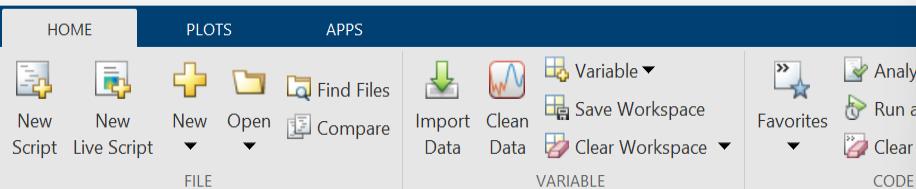
ABOUT

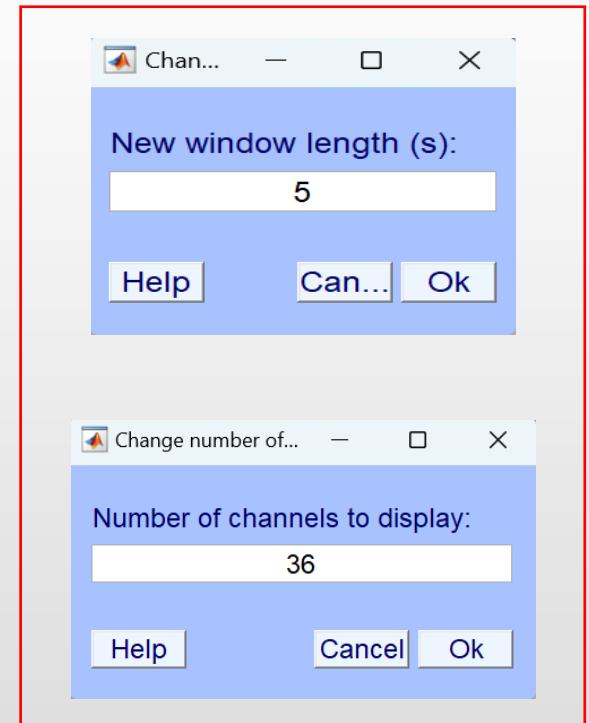
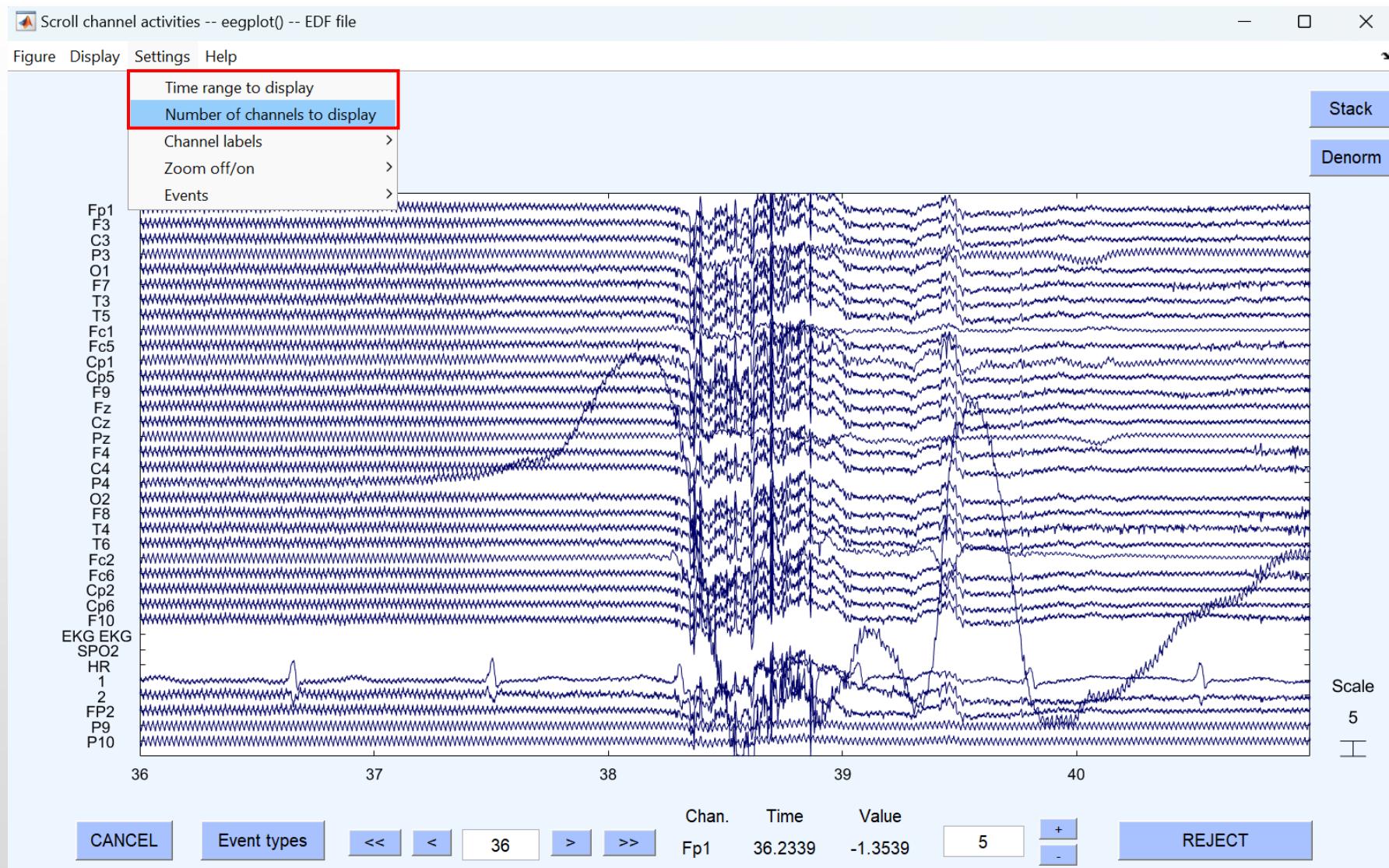
QUIT

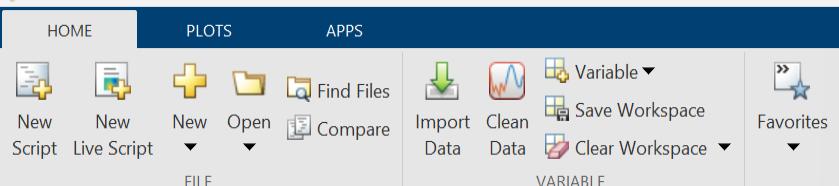
HELP

PREFERENCES









C: > Users > ASUS > Documents > MATLAB >

Workspace

Name	Value
ALLCOM	1x4 cell
ALLEEG	1x1 struct
CURRENTS...	1
CURRENTS...	0
EEG	1x1 struct
globalvars	8x1 cell
LASTCOM	"
PLUGINLIST	1x9 struct
STUDY	11
tmpEE	EEGLAB v2023.0

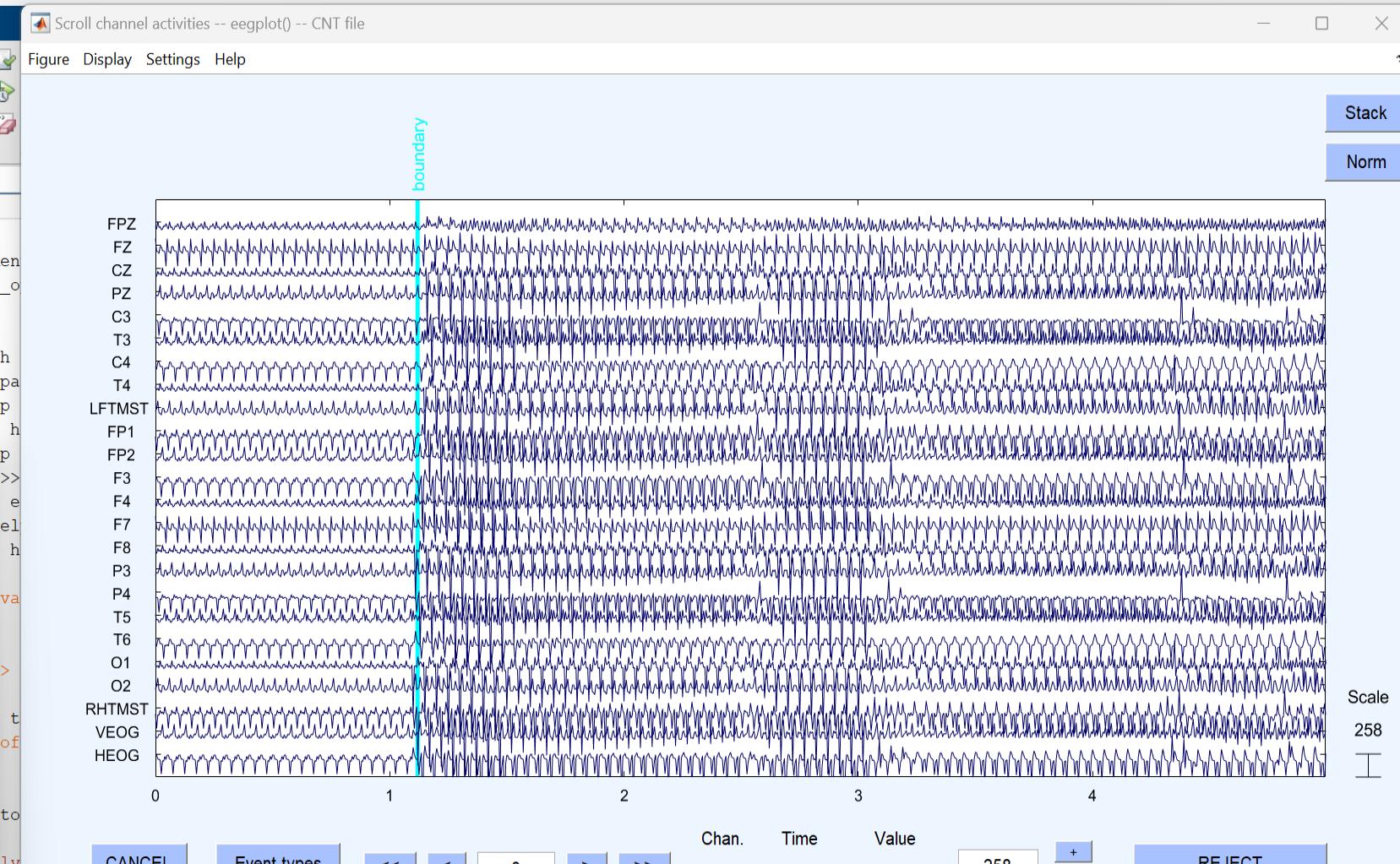
EEGLAB v2023.0

File Edit Tools Plot Study Datasets Help

- # (Expand tool choices via "File > Preferences")
- Change sampling rate
- Filter the data
- Re-reference the data
- Interpolate electrodes
- Inspect/reject data by eye
- Reject data using Clean Rawdata and ASR
- Decompose data by ICA
- Inspect/label components by map
- Classify components using ICLabel
- Remove components from data
- Extract epochs
- Remove epoch baseline
- Source localization using DIPFIT

ICA weights No

Dataset size (Mb) 18.6



CANCEL Event types << < 0 > >>

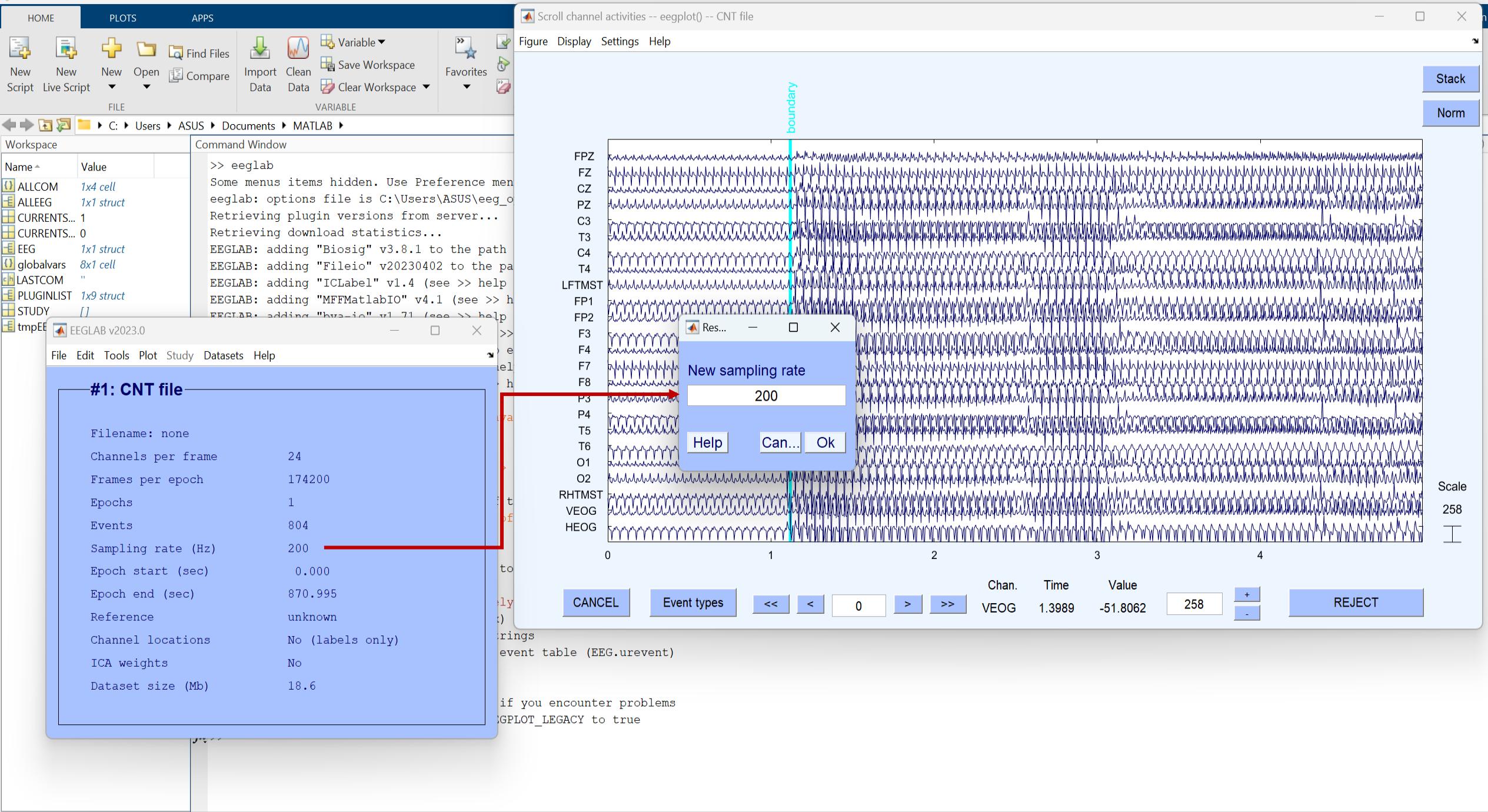
event table (EEG.urevent)

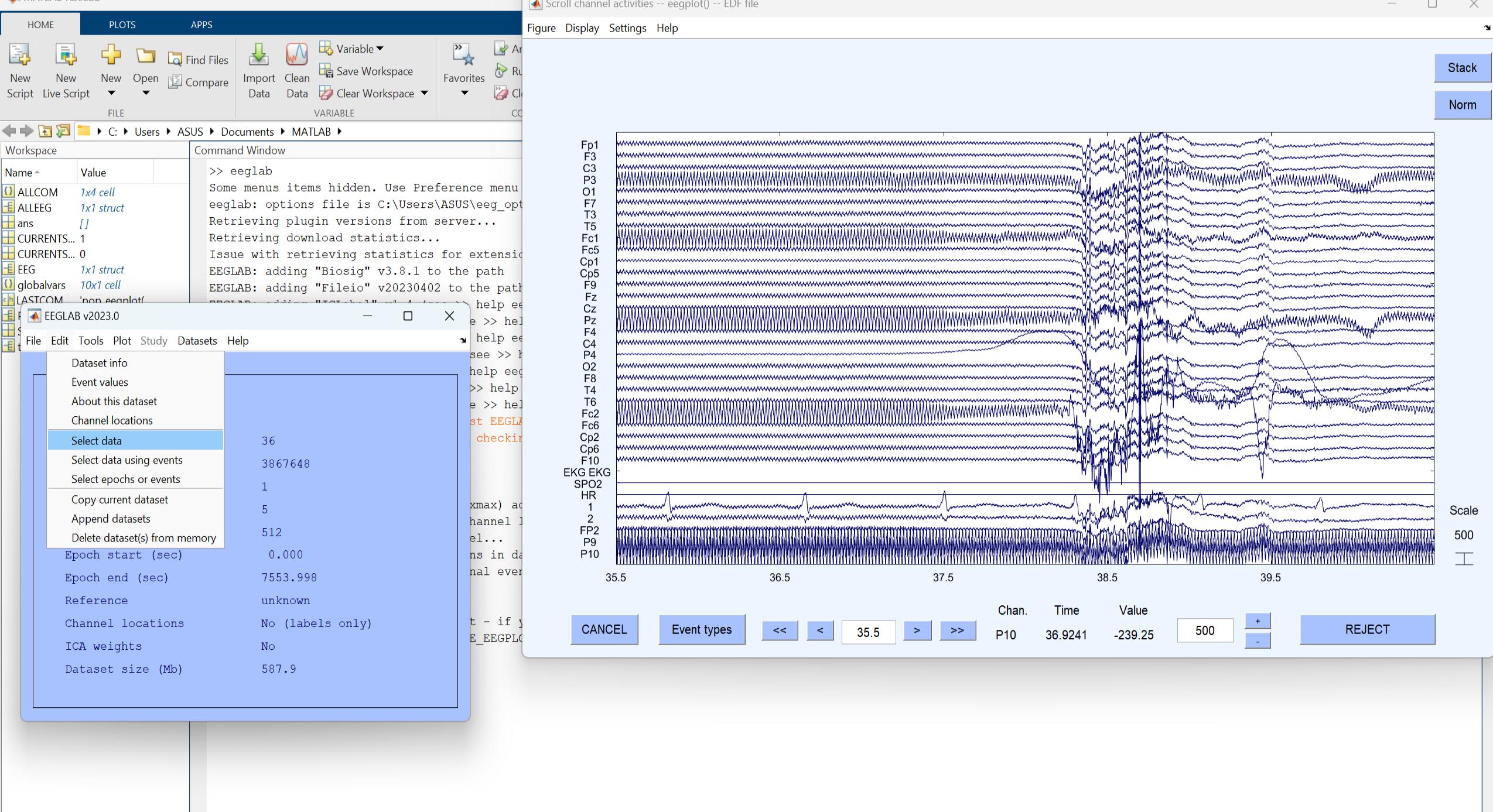
if you encounter problems
set EGGPLOT_LEGACY to true

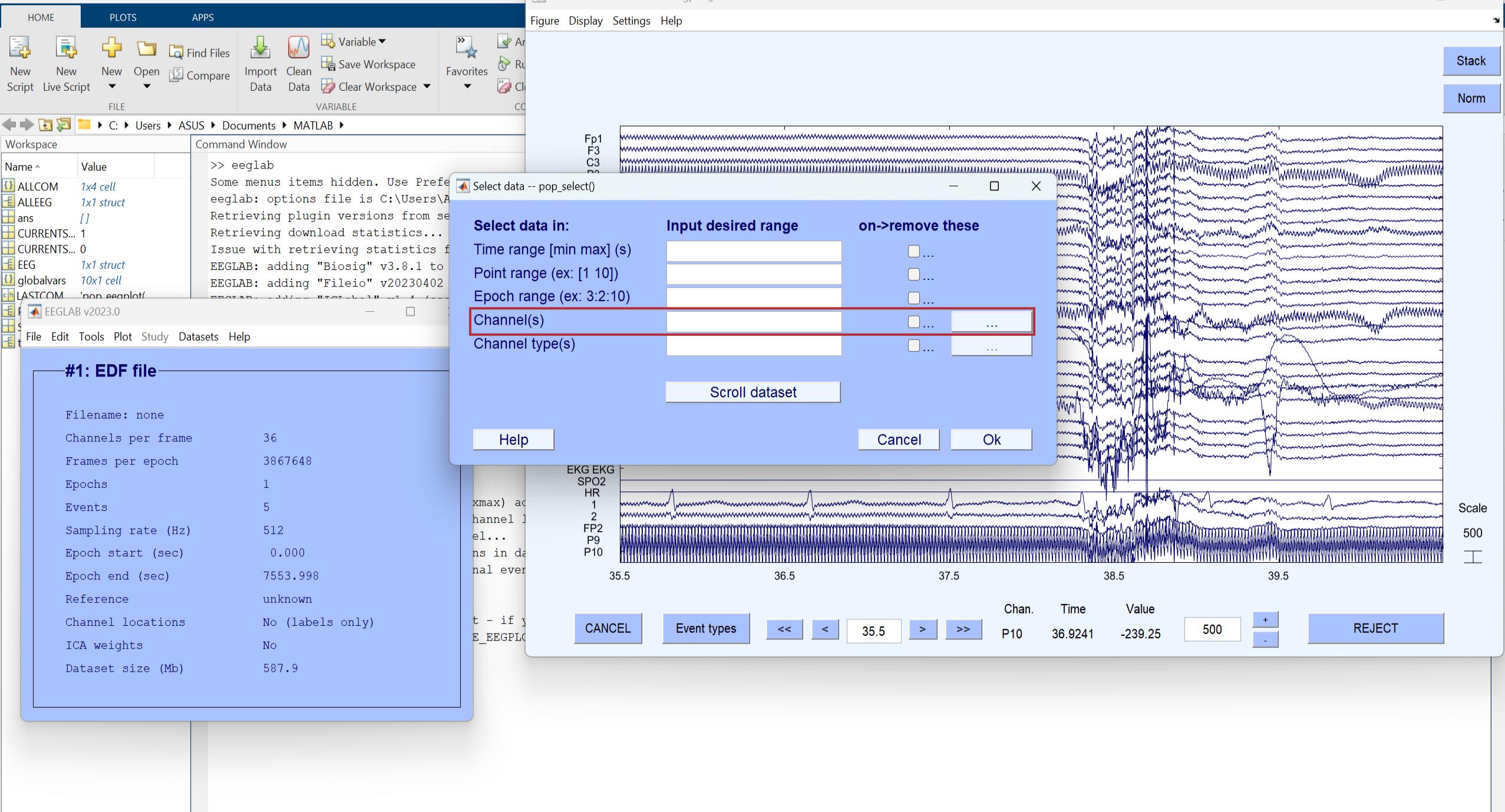
Stack

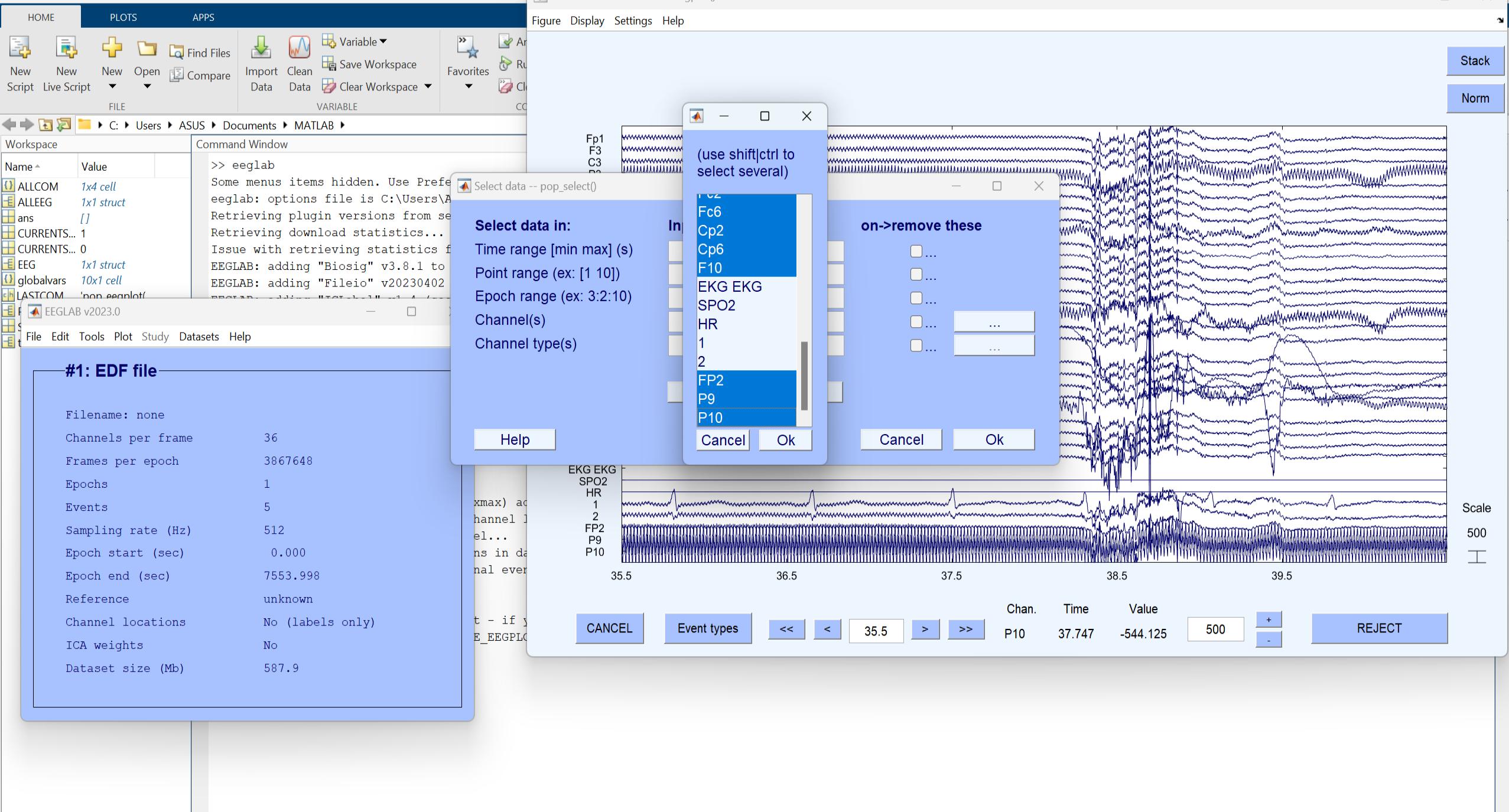
Norm

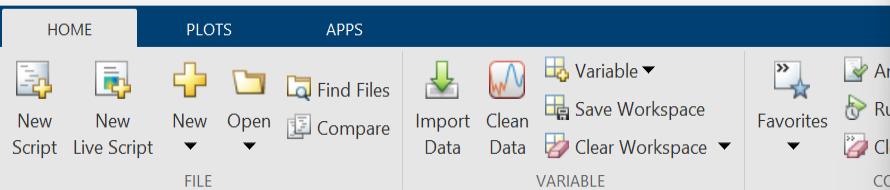
Command Window











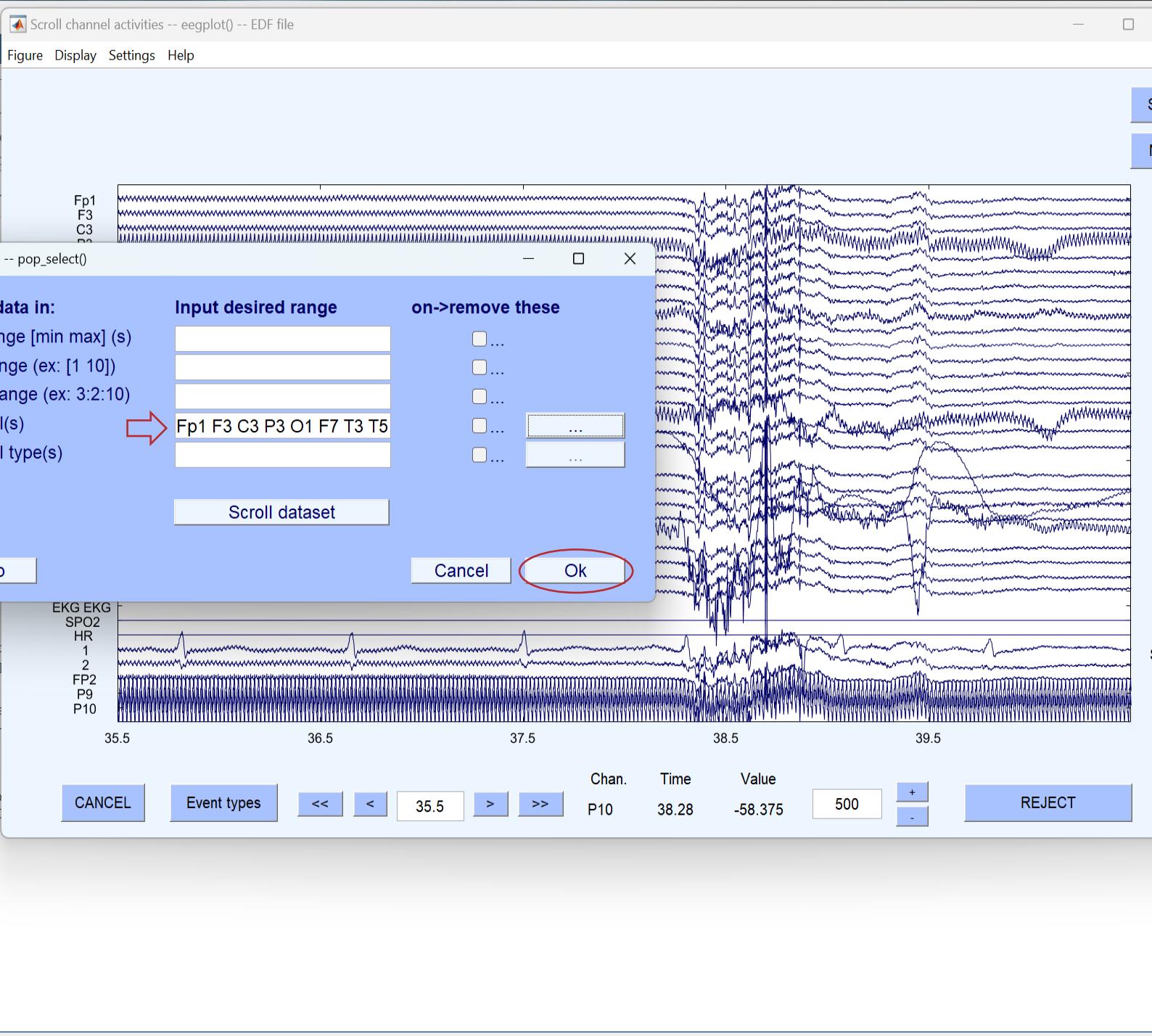
C: \ Users \ ASUS \ Documents \ MATLAB \

Workspace	
Name	Value
ALLCOM	1x4 cell
ALLEG	1x1 struct
ans	[]
CURRENTS...	1
CURRENTS...	0
EEG	1x1 struct
globalvars	10x1 cell
LASTCOM	'non_eegplot'
EEGLAB v2023.0	

File Edit Tools Plot Study Datasets Help

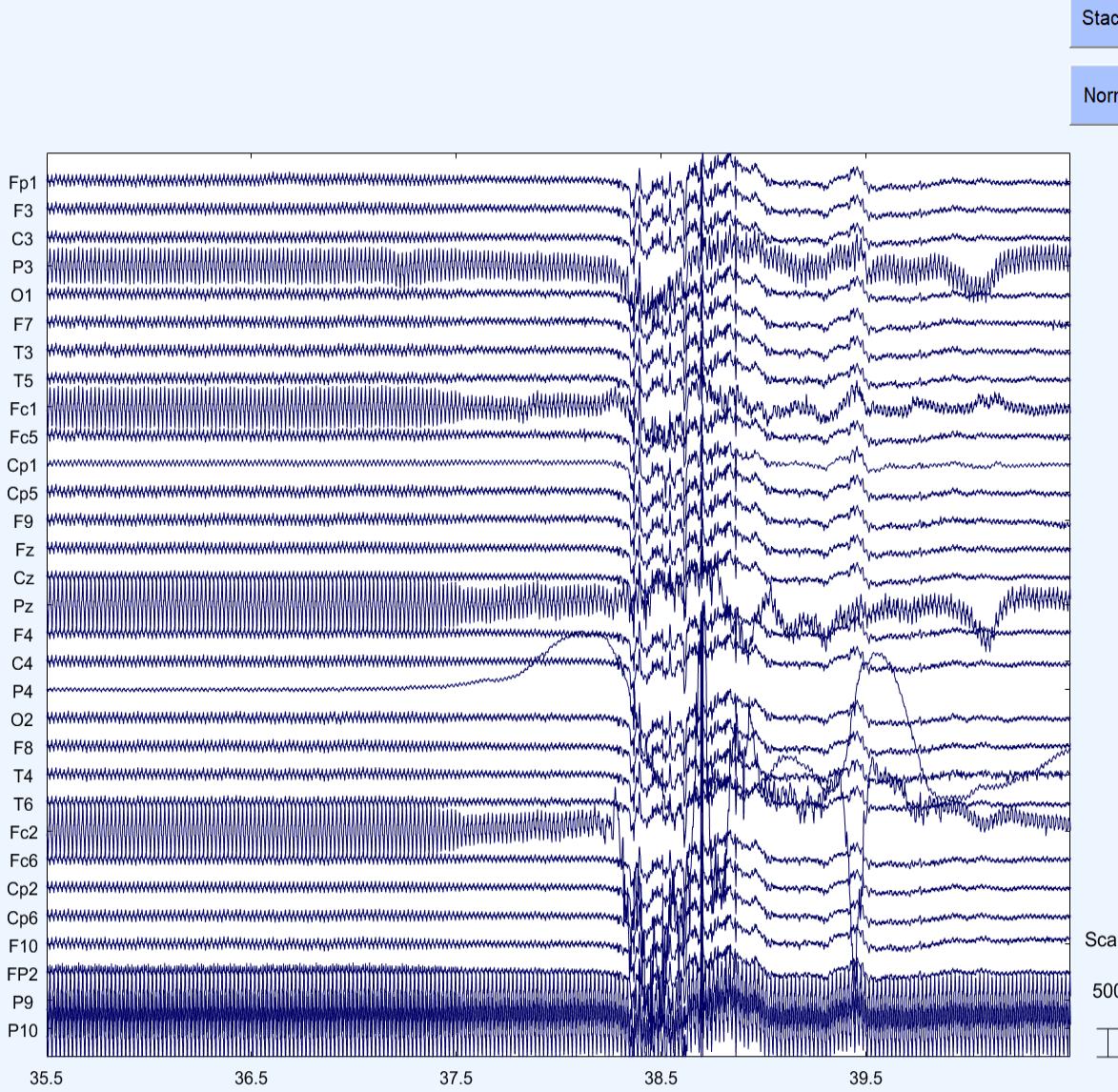
#1: EDF file

Filename: none
 Channels per frame 36
 Frames per epoch 3867648
 Epochs 1
 Events 5
 Sampling rate (Hz) 512
 Epoch start (sec) 0.000
 Epoch end (sec) 7553.998
 Reference unknown
 Channel locations No (labels only)
 ICA weights No
 Dataset size (Mb) 587.9



Scroll channel activities -- eegplot() -- EDF file

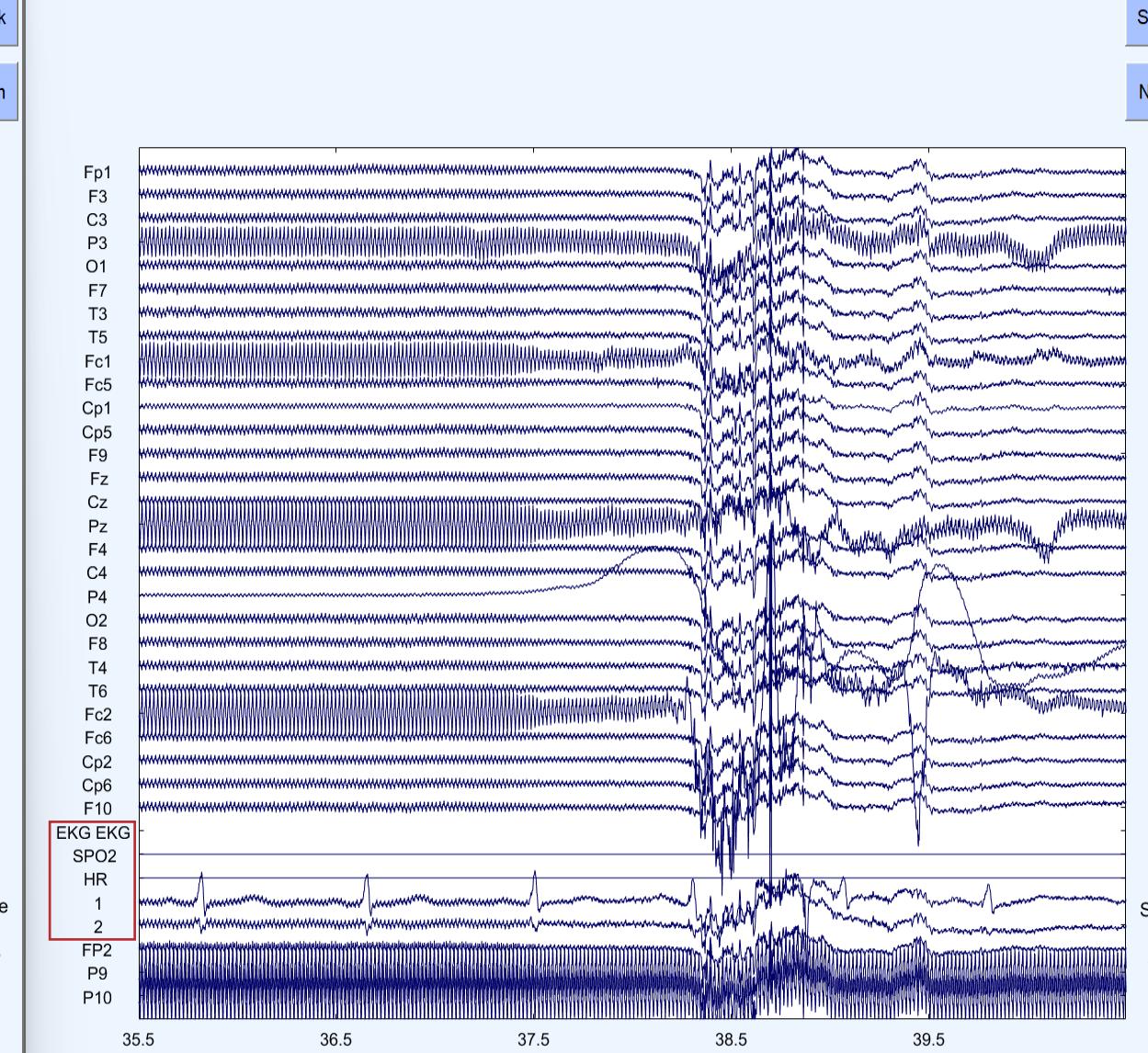
Figure Display Settings Help



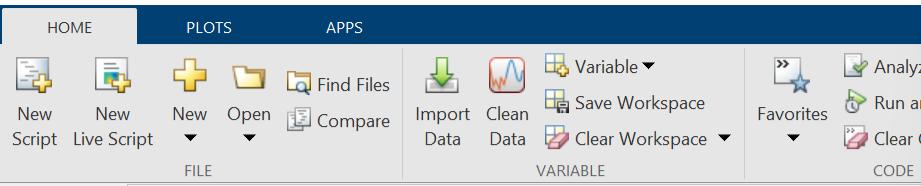
	Chan.	Time	Value										
CANCEL	Event types	<<	<	35.5	>	>>	Fc1	40.8607	-49	500	+	-	REJECT

Scroll channel activities -- eegplot() -- EDF file

Figure Display Settings Help

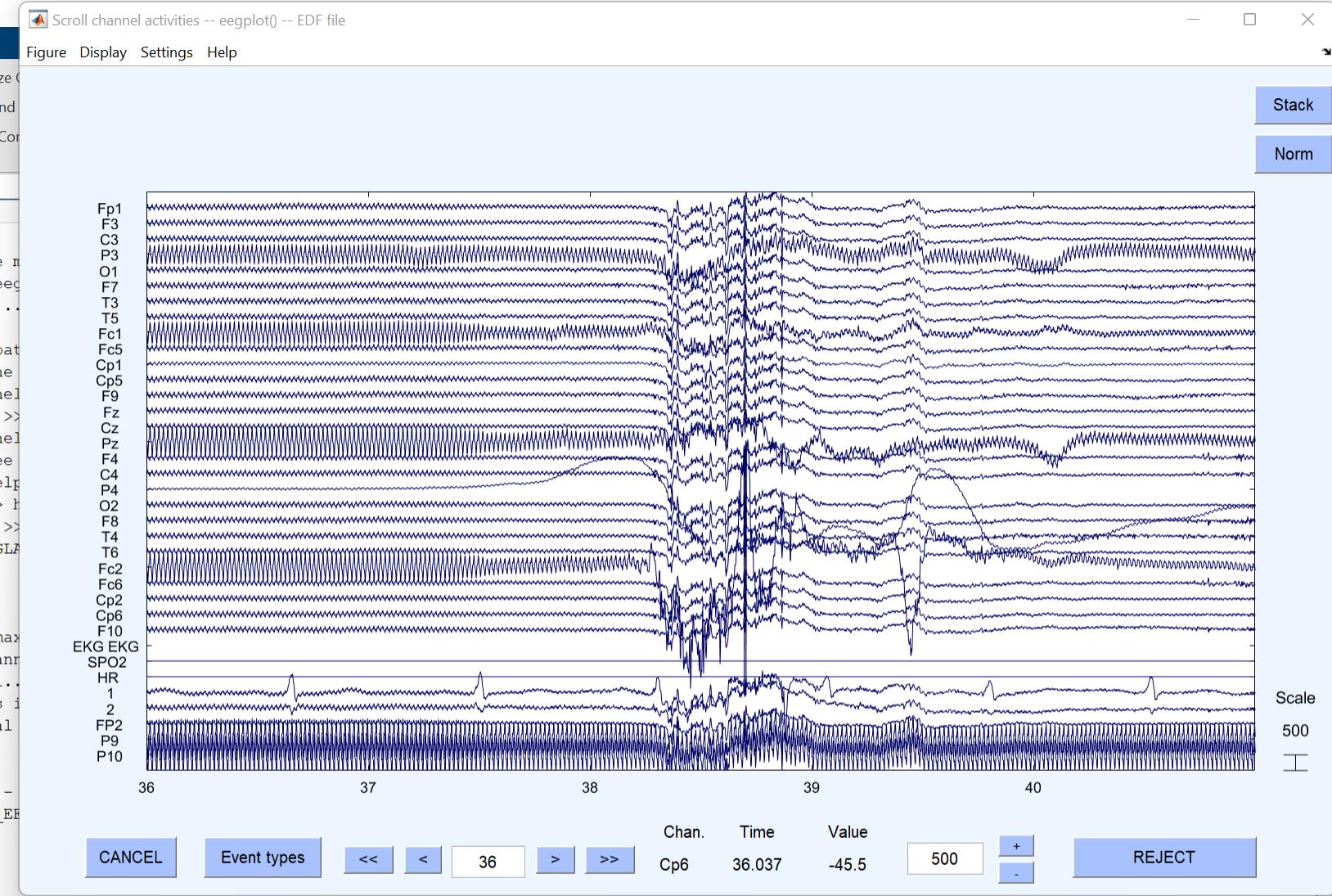


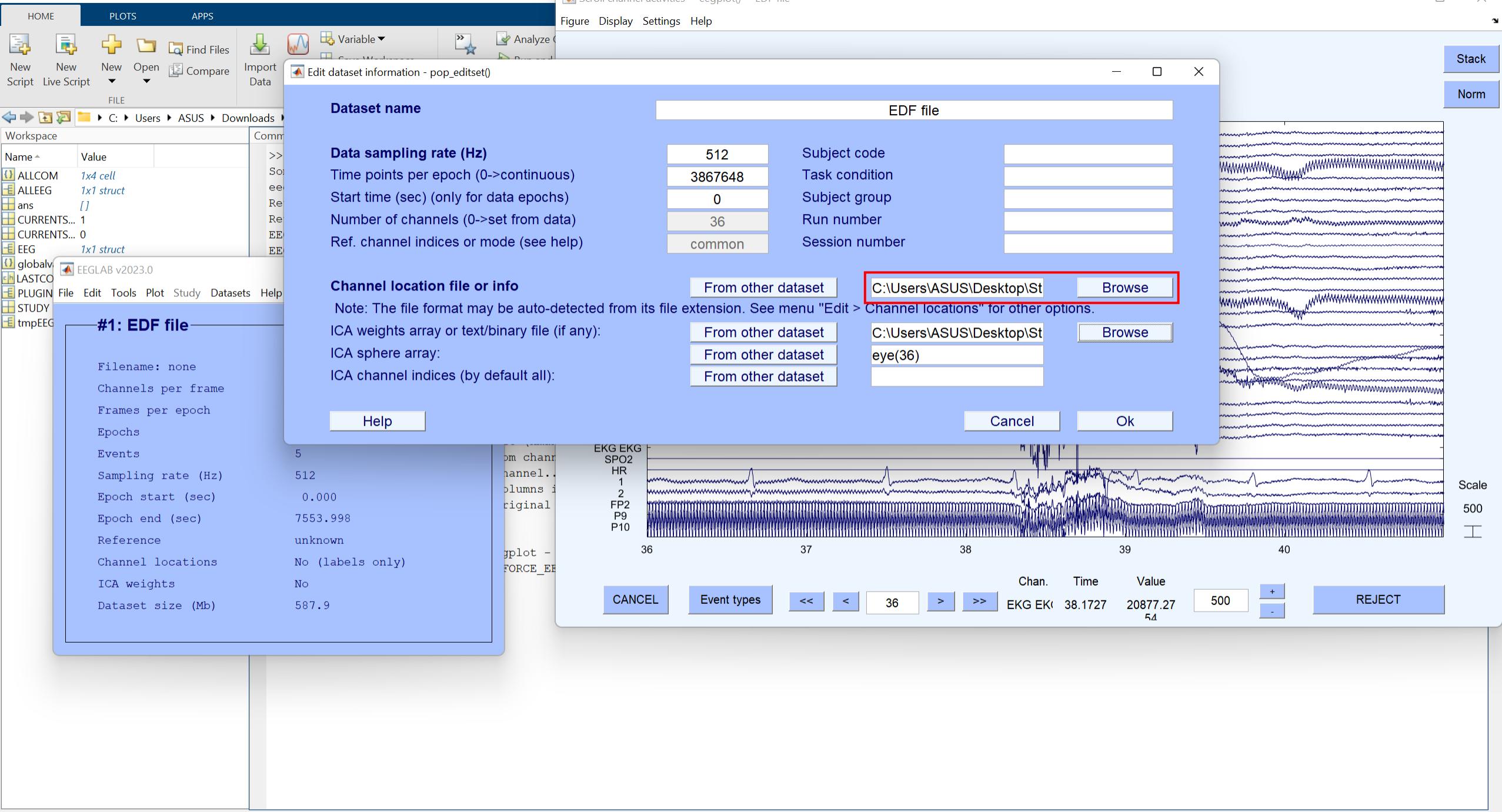
	Chan.	Time	Value										
CANCEL	Event types	<<	<	35.5	>	>>	P10	37.9382	386.375	500	+	-	REJECT

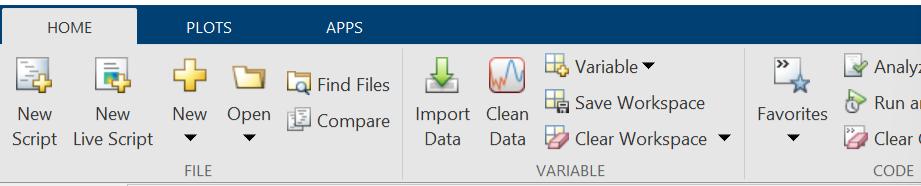


C:\Users\ASUS\Downloads>

Workspace		Command Window
Name	Value	
ALLCOM	1x4 cell	>> eeglab Some menus items hidden. Use Preference m...
ALLEEG	1x1 struct	eeglab: options file is C:\Users\ASUS\eed...
ans	[]	Retrieving plugin versions from server...
CURRENTS...	1	Retrieving download statistics...
CURRENTS...	0	EEGLAB: adding "Biosig" v3.8.1 to the pat...
EEG	1x1 struct	EEGLAB: adding "Fileio" v20230402 to the
globalv		>> hel (see >> help) 8 (see >> help) of EEGLAB
LASTCO		>> help (see >> help) of EEGLAB
PLUGIN		>> help (see >> help) of EEGLAB
STUDY		>> help (see >> help) of EEGLAB
tmpEEG		>> help (see >> help) of EEGLAB

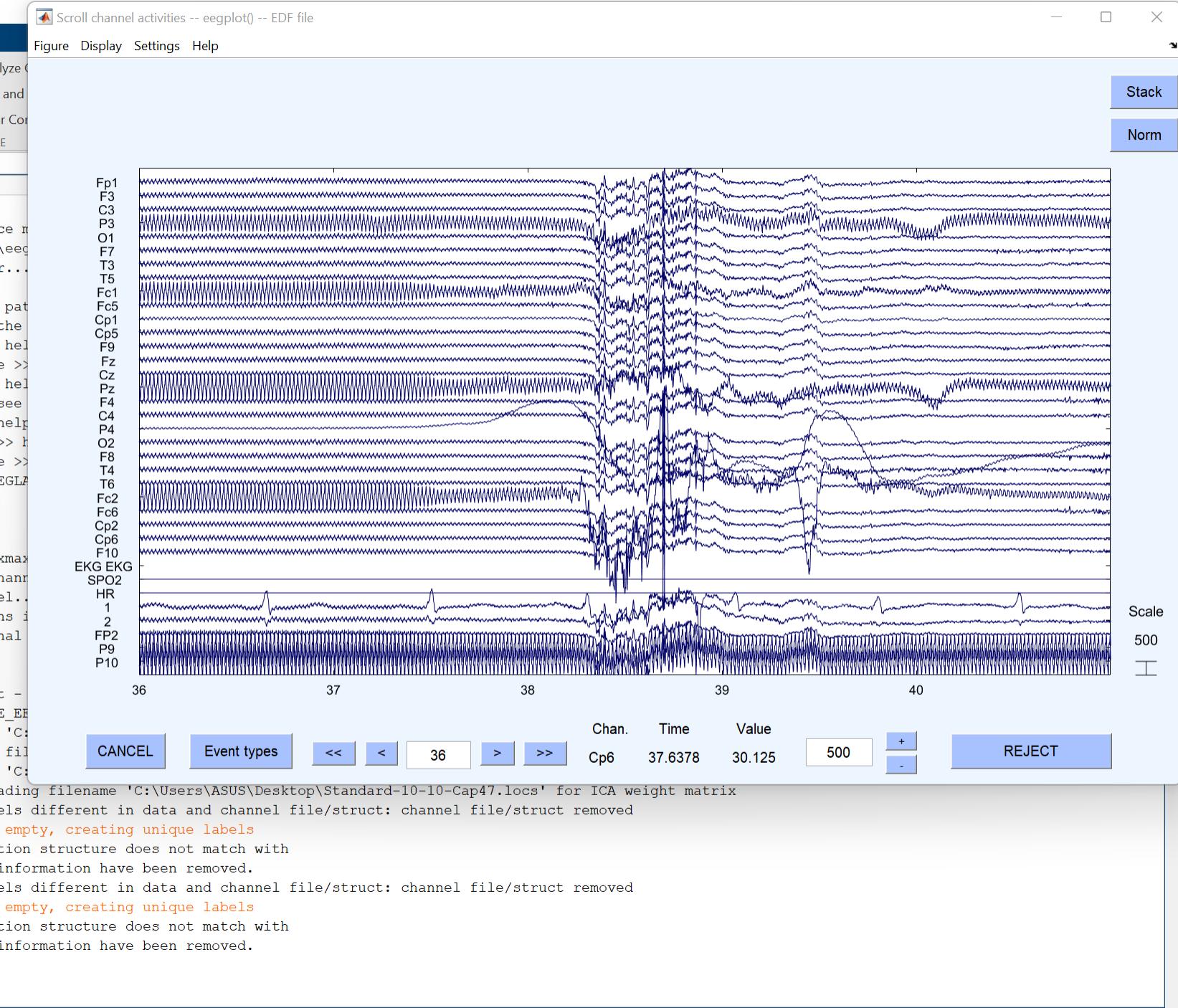


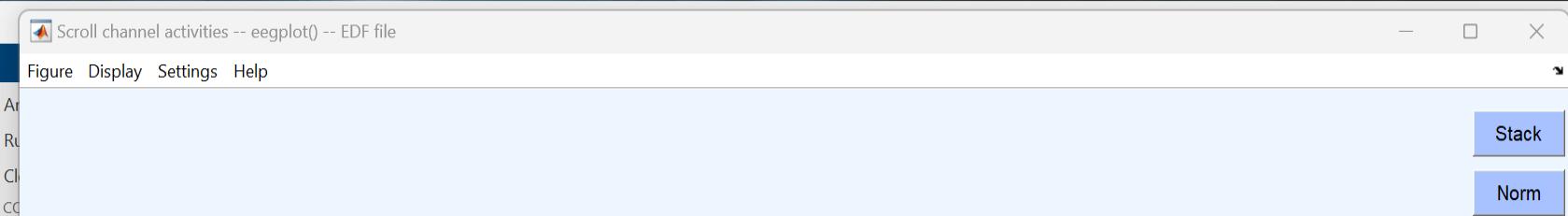
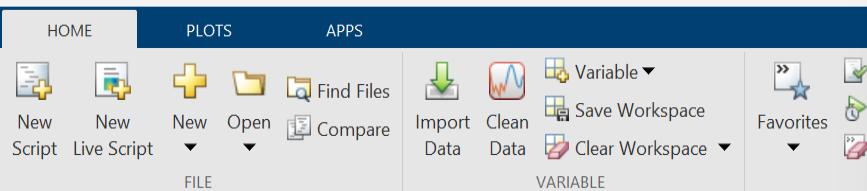




C: > Users > ASUS > Downloads >

Workspace		Command Window
Name	Value	
ALLCOM	1x6 cell	>> eeglab Some menus items hidden. Use Preference menu to show them.
ALLEEG	1x1 struct	eeglab: options file is C:\Users\ASUS\eedglab\options.edg
ans	[]	Retrieving plugin versions from server...
CURRENTS...	1	Retrieving download statistics...
CURRENTS...	0	EEGLAB: adding "Biosig" v3.8.1 to the path
EEG	1x1 struct	EEGLAB: adding "Fileio" v20230402 to the path
globalv		
LASTCO		>> help eeglab (see >> help eeglab)
PLUGIN		>> help eeglab (see >> help eeglab)
STUDY		of EEGLAB
tmpEEG		OFF"





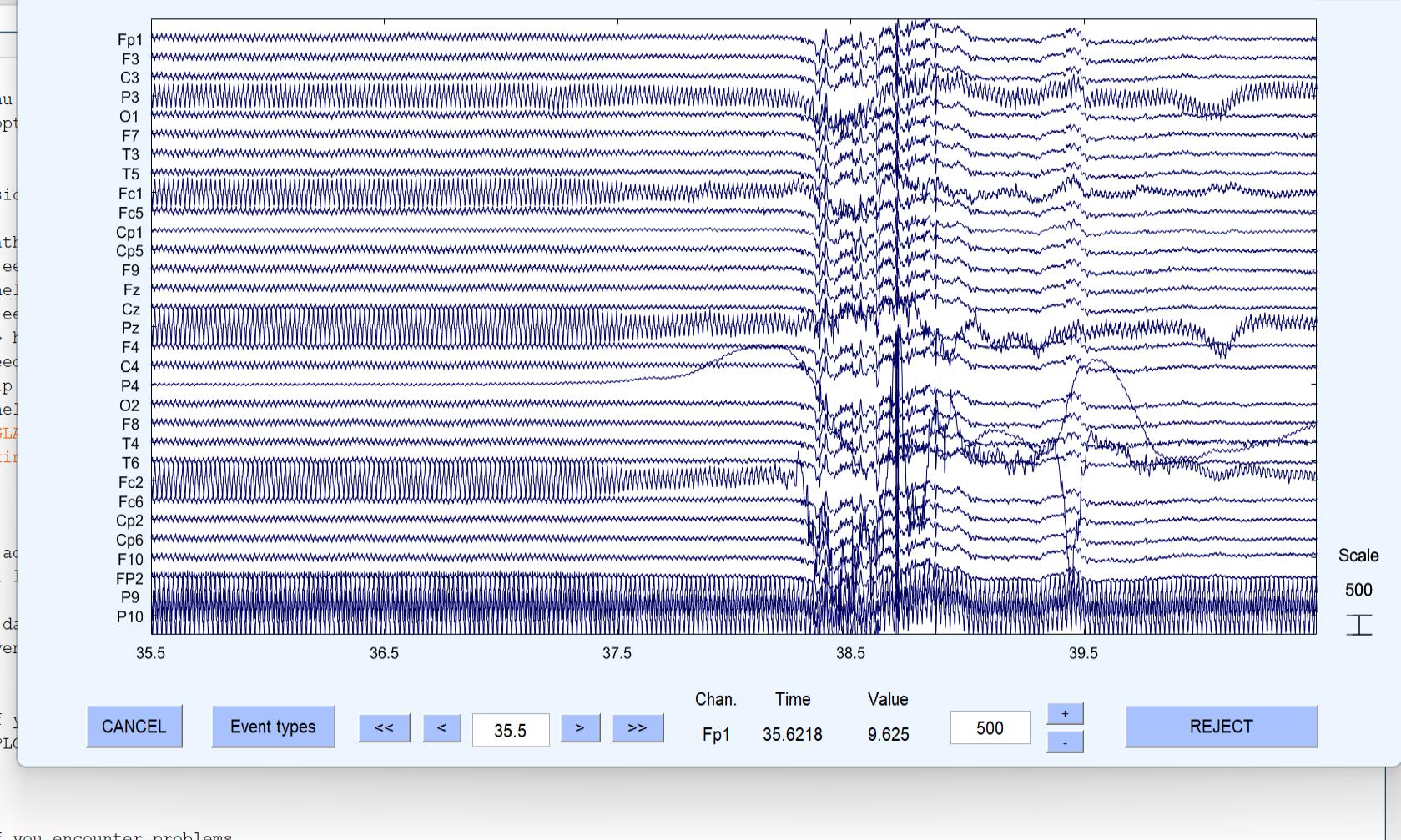
Workspace

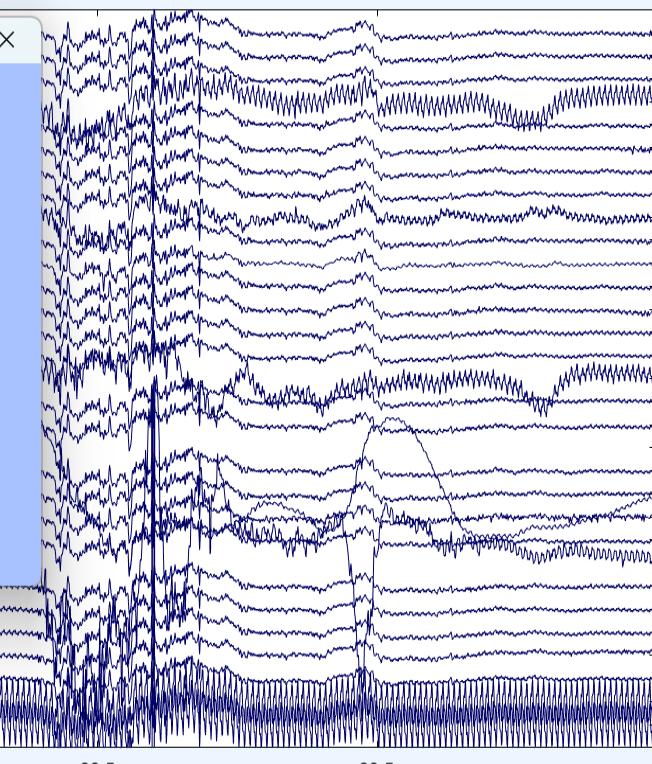
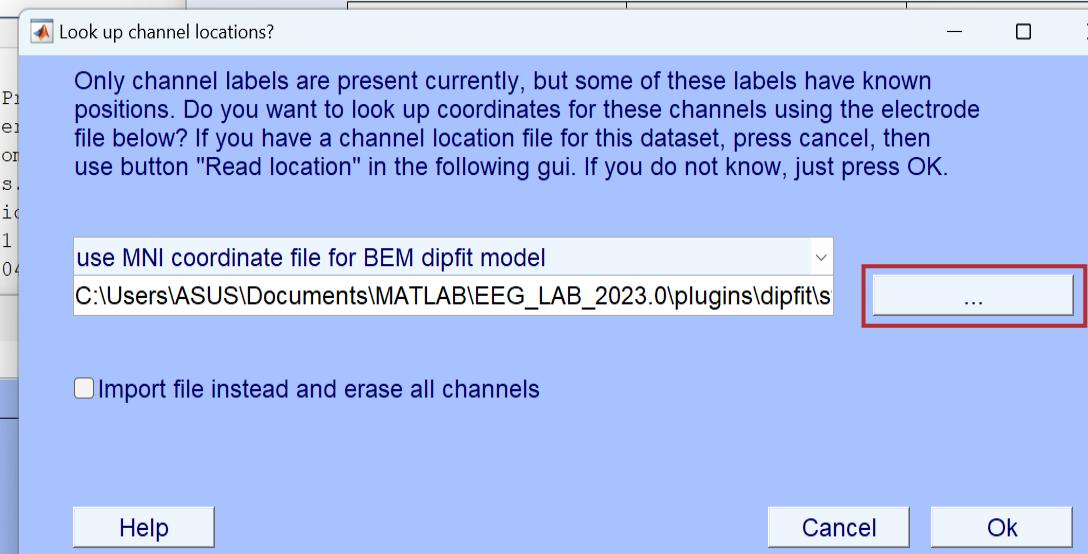
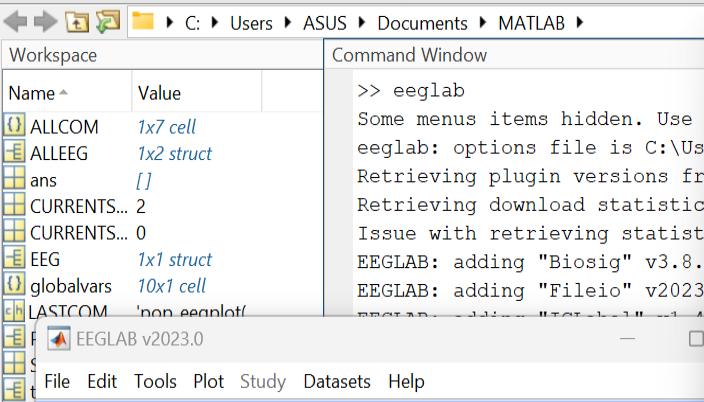
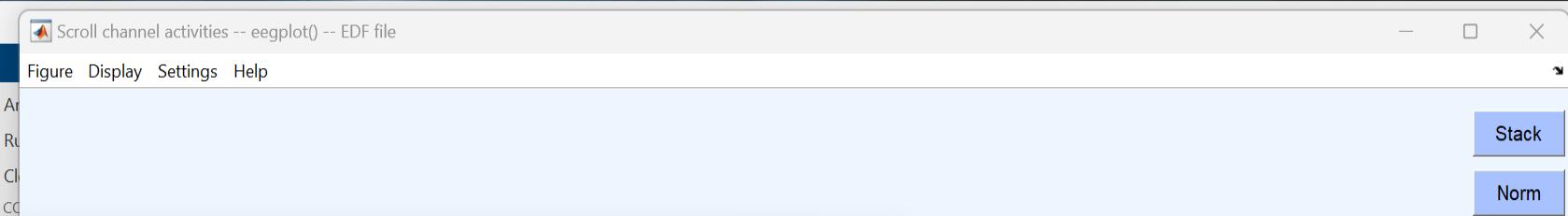
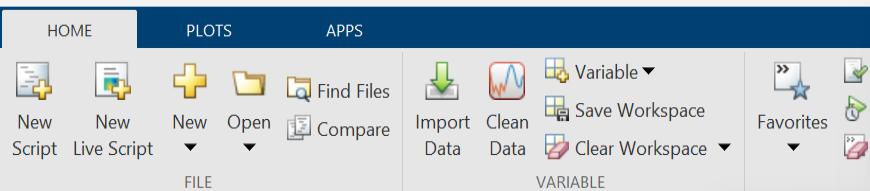
Name	Value
ALLCOM	1x7 cell
ALLEEG	1x2 struct
ans	[]
CURRENTS...	2
CURRENTS...	0
EEG	1x1 struct
globalvars	10x1 cell
LASTCOM	'non_eegplot'
EEGLAB v2023.0	

Command Window

```
>> eeglab
Some menus items hidden. Use Preference menu
eeglab: options file is C:\Users\ASUS\eeg_opt
Retrieving plugin versions from server...
Retrieving download statistics...
Issue with retrieving statistics for extension
EEGLAB: adding "Biosig" v3.8.1 to the path
EEGLAB: adding "Fileio" v20230402 to the path
EEGLAB: adding "Talairach" v1.0 to the path
help ee
e >> hel
help ee
see >> l
help ee
>> help
e >> hel
st EEGLA
checkin
xmax) ac
channel I
el...
ns in da
nal even
t - if y
E_EEGPL

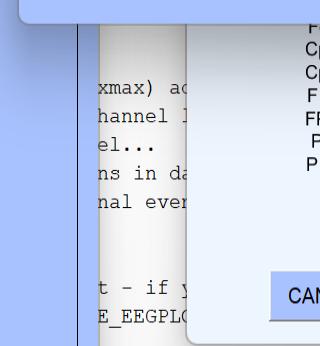
```



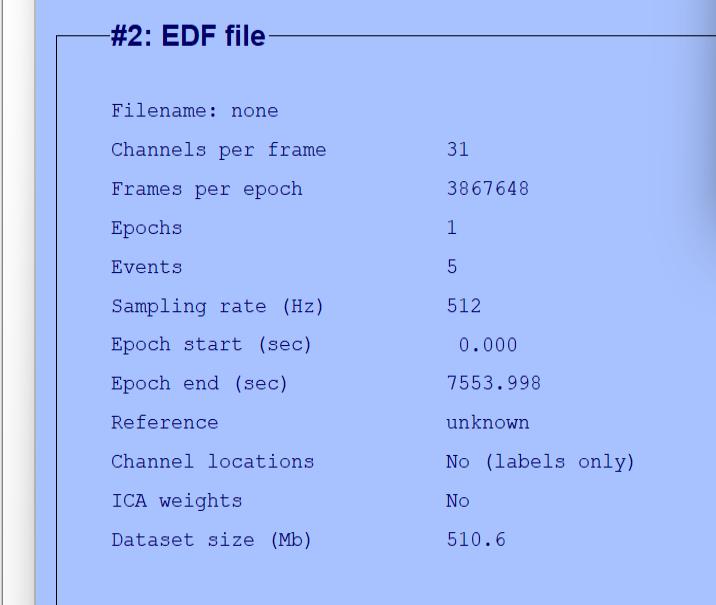
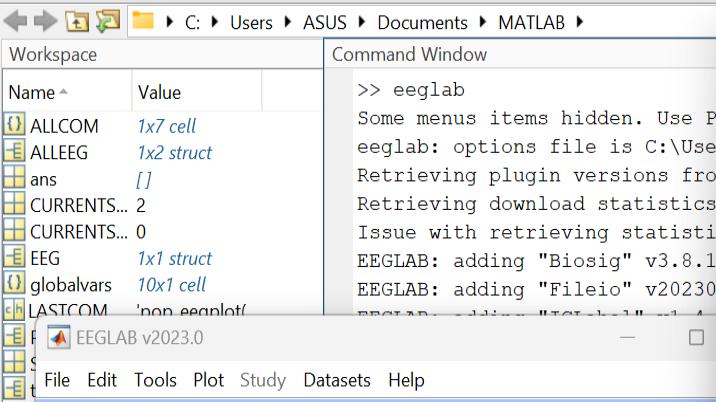
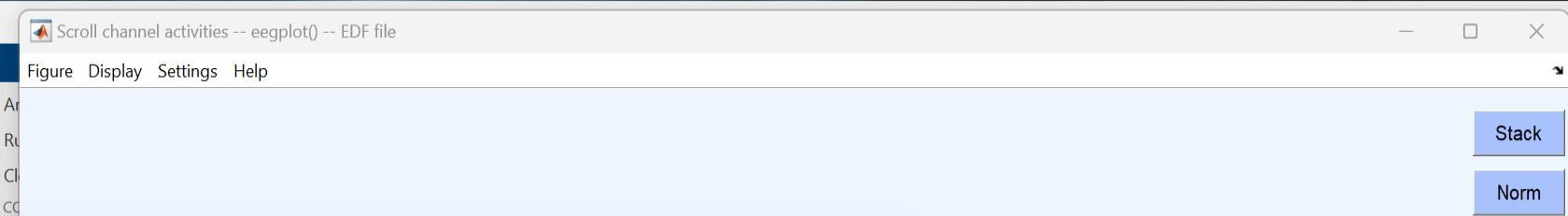
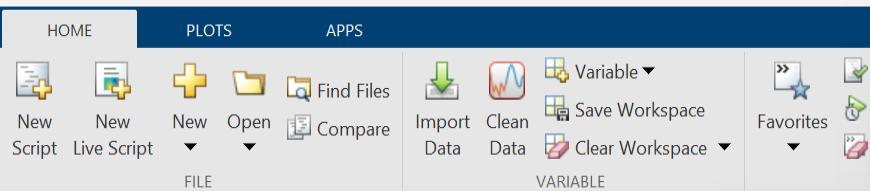


Chan.	Time	Value
P10	36.8024	-118.875

+ - REJECT

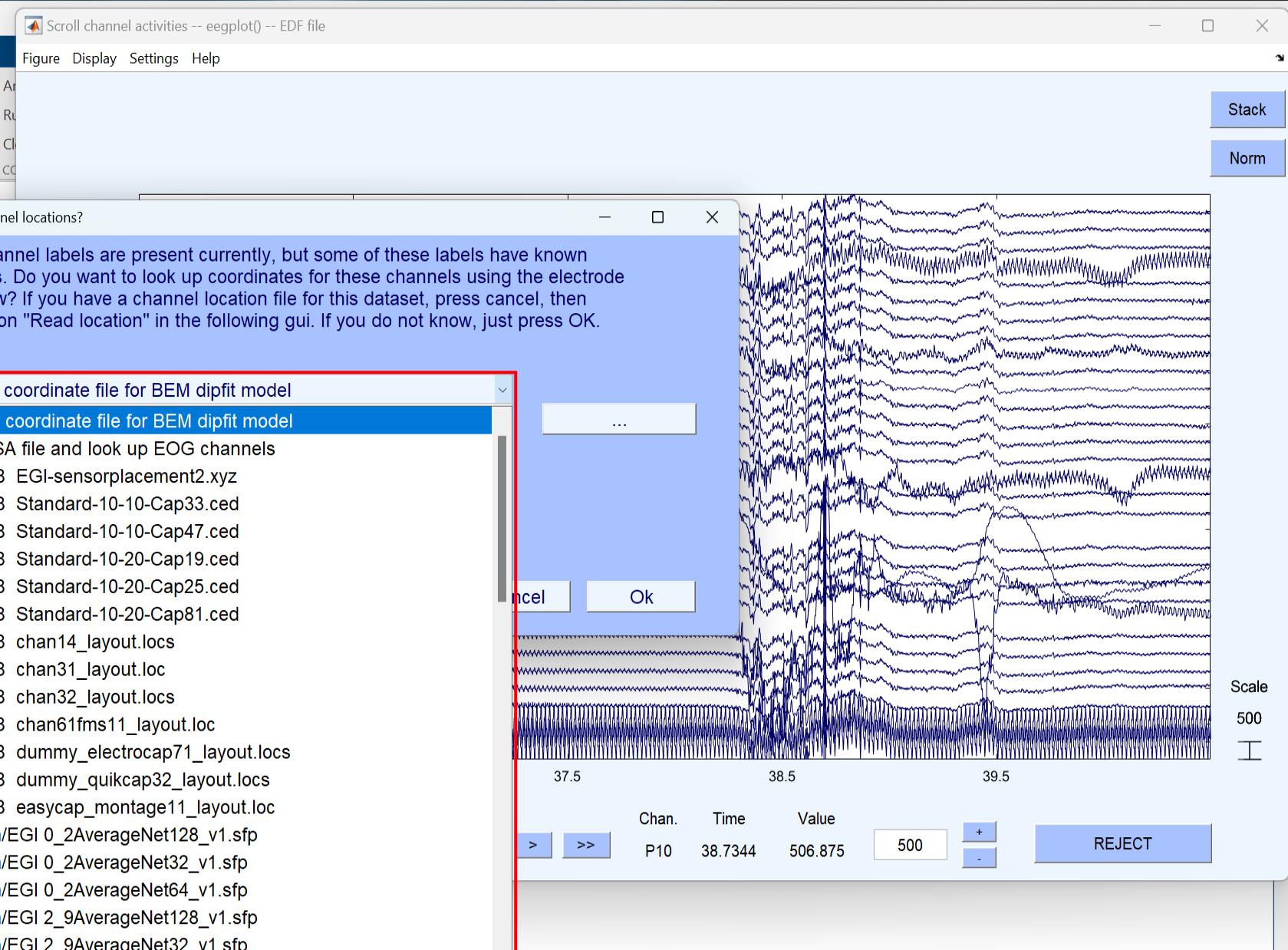


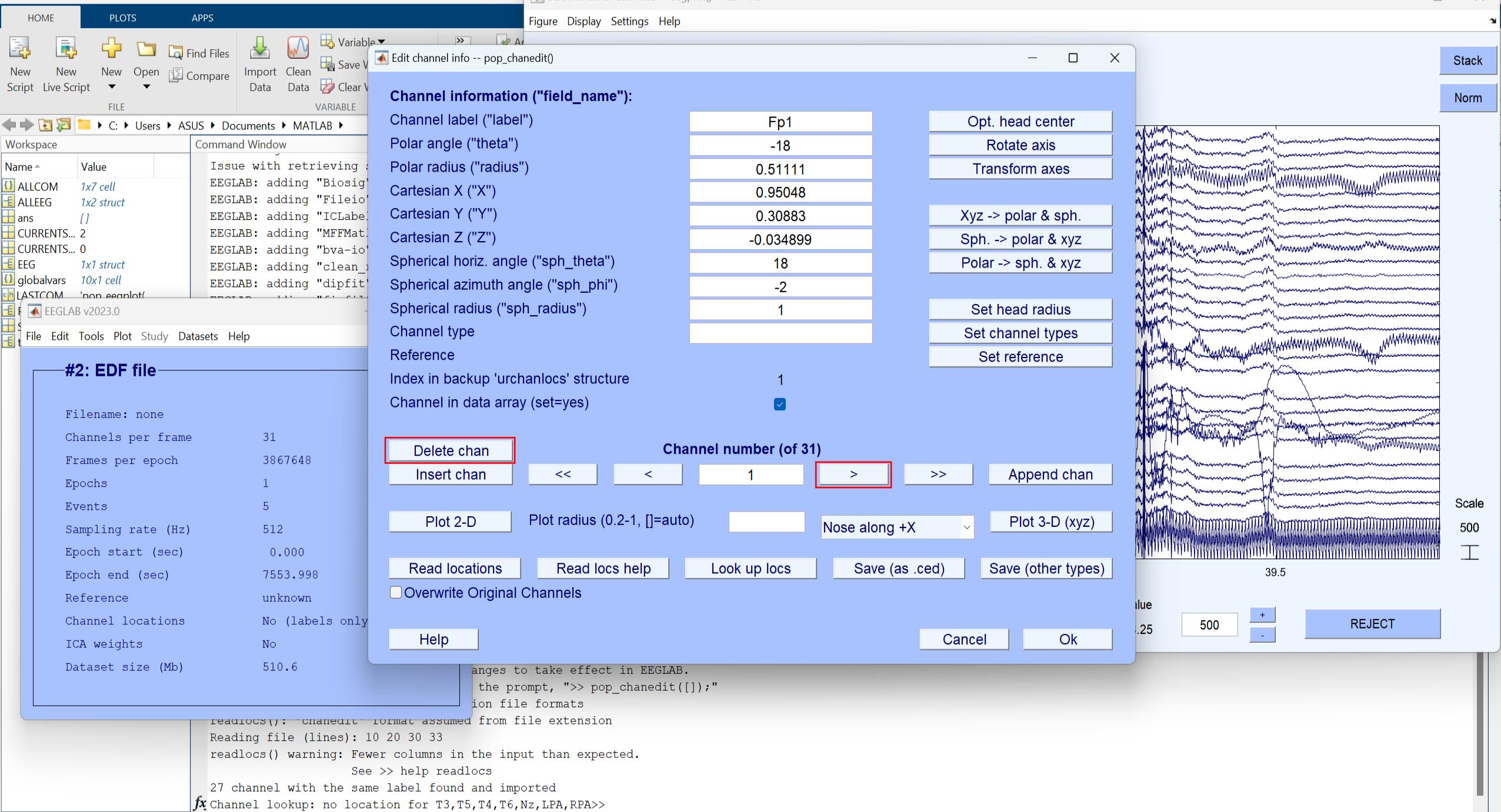
fx >>

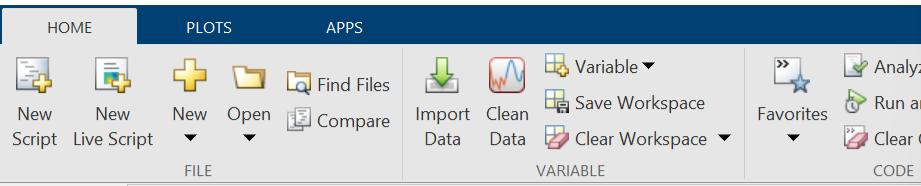


```
type edit eegplot.m and change FORCE_EEGPLOT_LEGACY to true
IMPORTANT: After importing/modifying data channels, you must close
the channel editing window for the changes to take effect in EEGLAB.
TIP: Call this function directly from the prompt, ">> pop_chanedit();"
      to convert between channel location file formats
```

fx >>







<

>

C:

Users > ASUS > Downloads >

Workspace

Name	Value
ALLCOM	1x6 cell
ALLEEG	1x1 struct
ans	[]
CURRENTS...	1
CURRENTS...	0
EEG	1x1 struct
globalv	
LASTCO	
PLUGIN	
File	
Edit	
Tools	
Plot	
Study	
Help	

EEGLAB v2023.0

STUDY

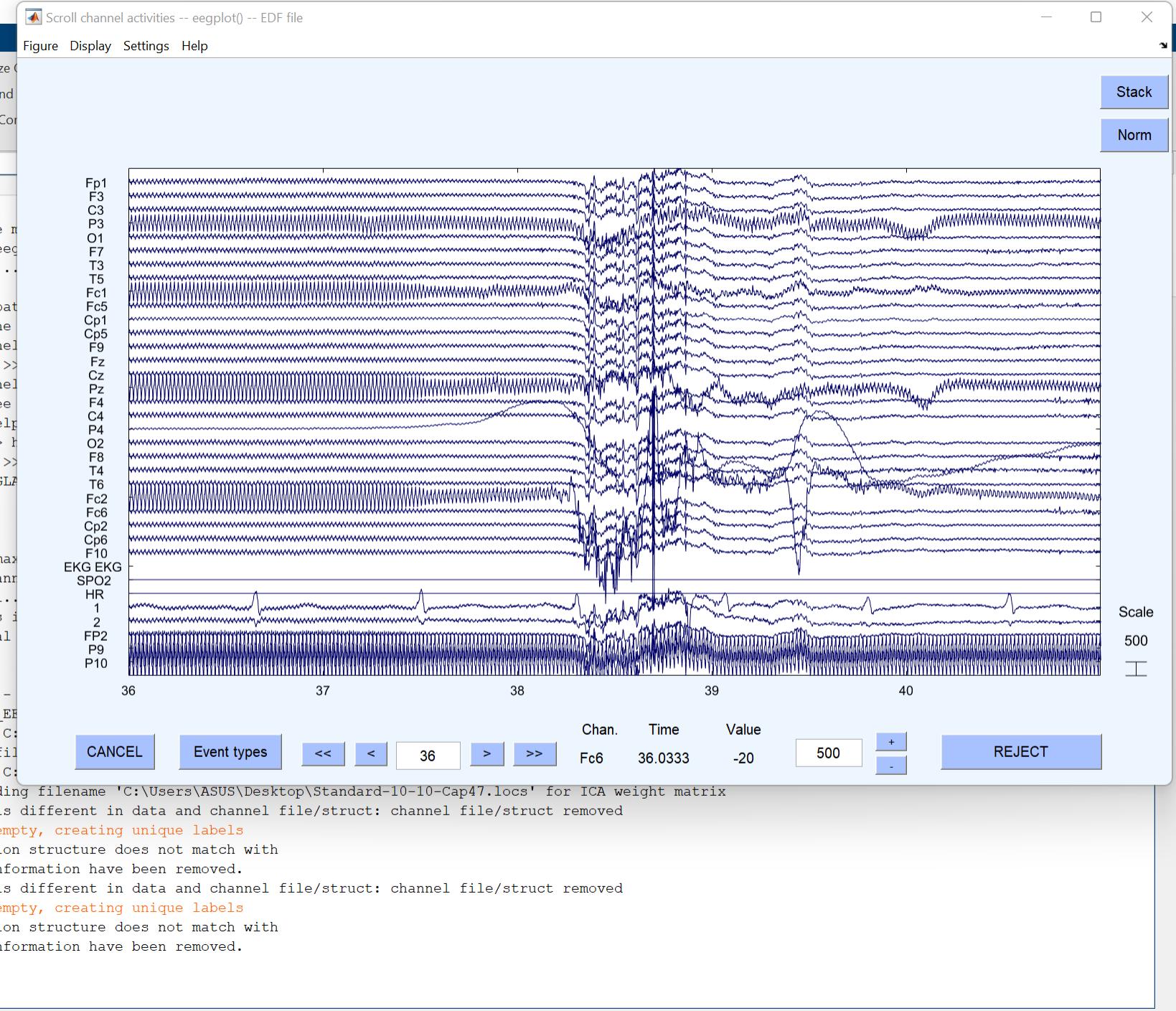
tmpEEG

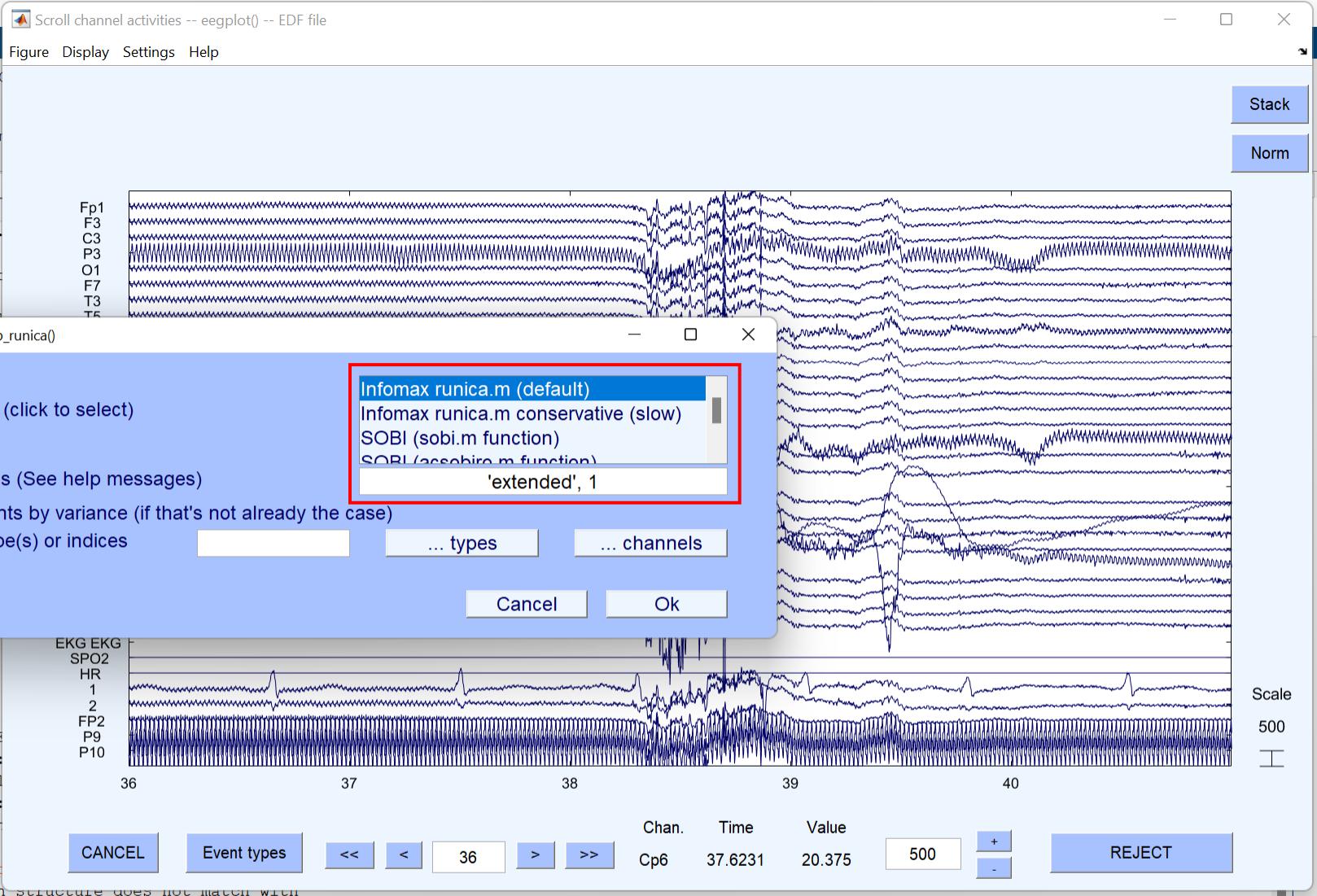
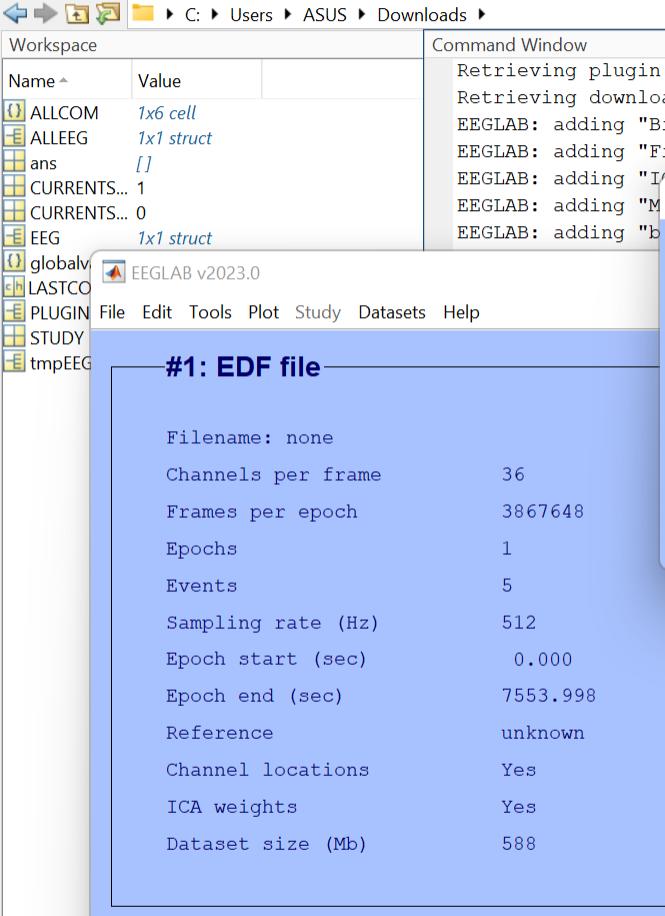
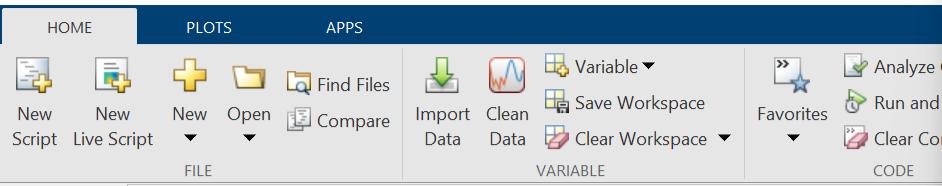
(Expand tool choices via "File > Preferences")

- Change sampling rate
- Filter the data
- Re-reference the data
- Interpolate electrodes
- Inspect/reject data by eye
- Reject data using Clean Rawdata and ASR
- Decompose data by ICA**
- Inspect/label components by map
- Classify components using ICLabel
- Remove components from data
- Extract epochs
- Remove epoch baseline
- Source localization using DIPFIT

ICA weights Yes

Dataset size (Mb) 588

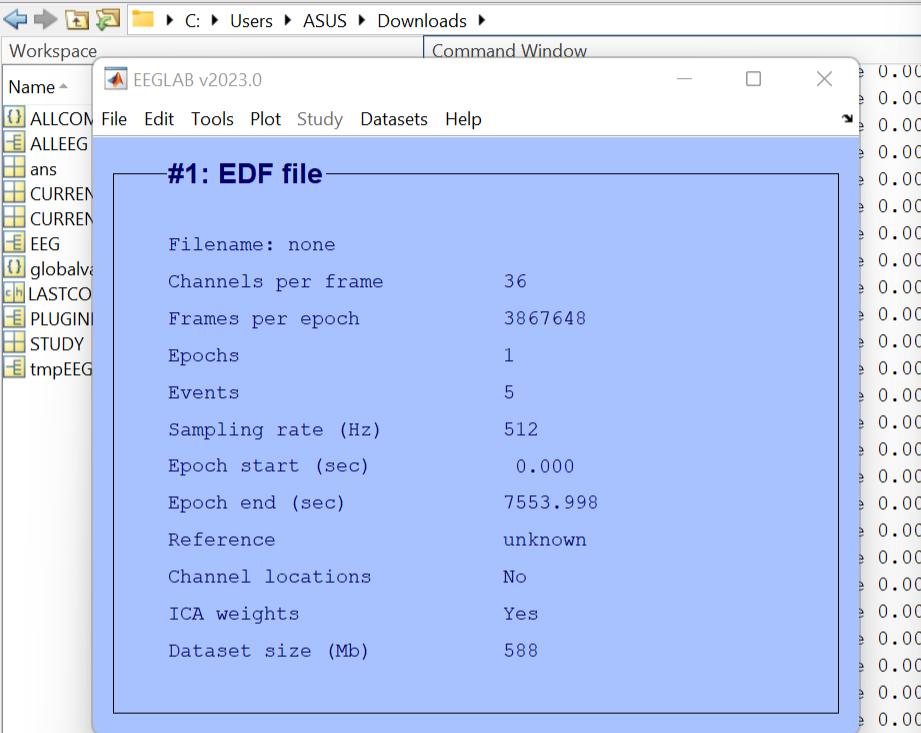
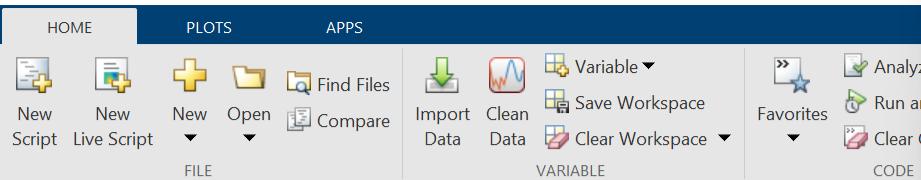




```
eeg_checkset warning: number of channels different in data and channel file/struct: channel file/struct removed
Warning: channel labels should not be empty, creating unique labels
Warning: the size of the channel location structure does not match with
number of channels. Channel information have been removed.
Done.
eeg_checkset warning: number of channels different in data and channel file/struct: channel file/struct removed
Warning: channel labels should not be empty, creating unique labels
Warning: the size of the channel location structure does not match with
number of channels. Channel information have been removed.
```

fx>>

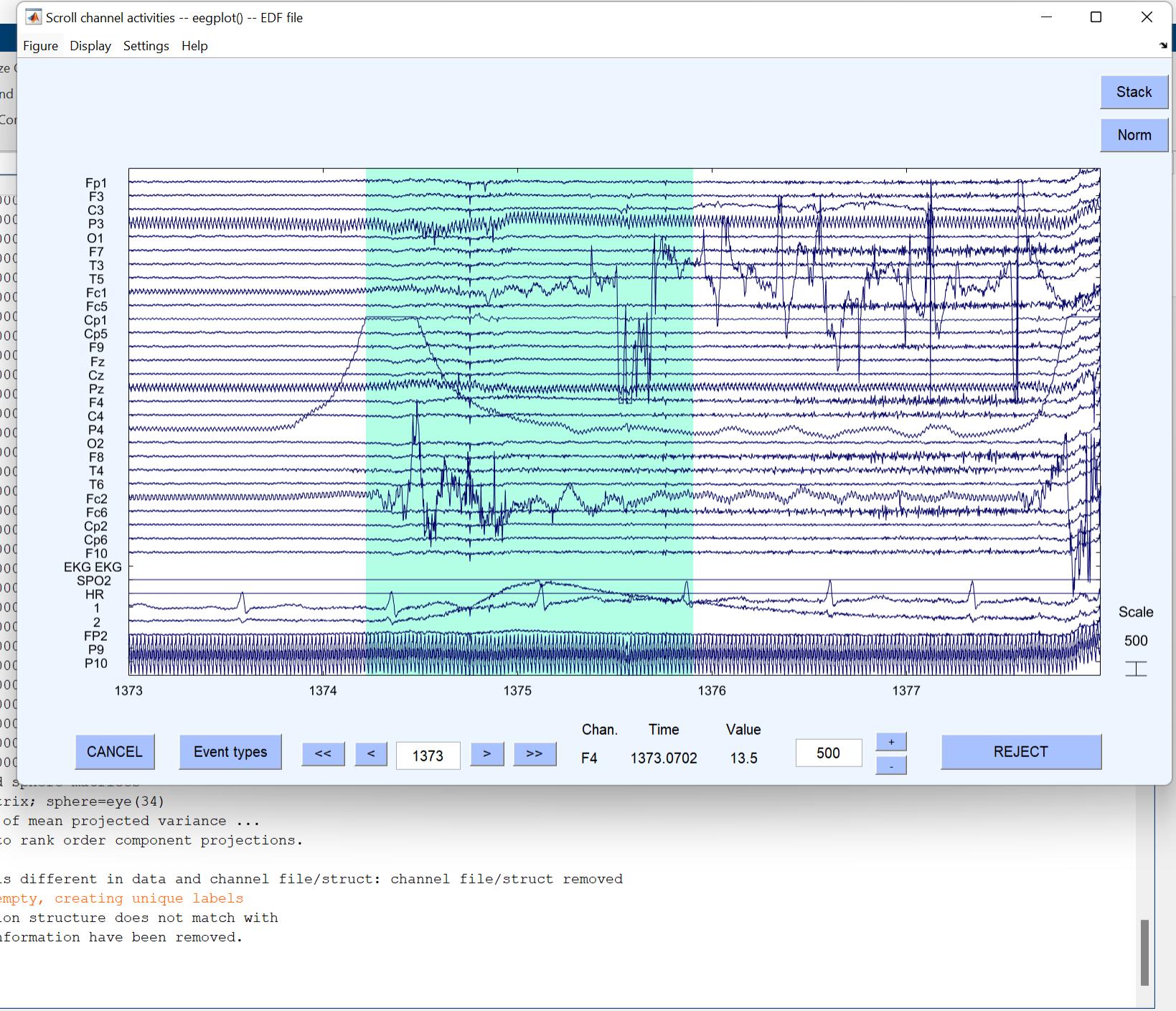
Stack
Norm

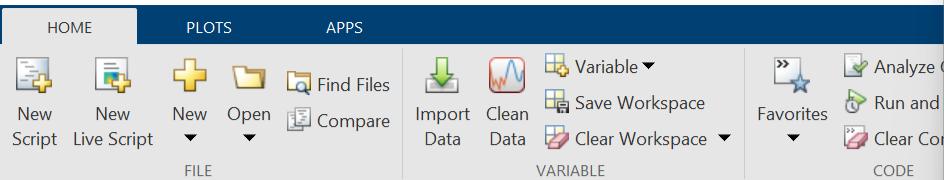


```

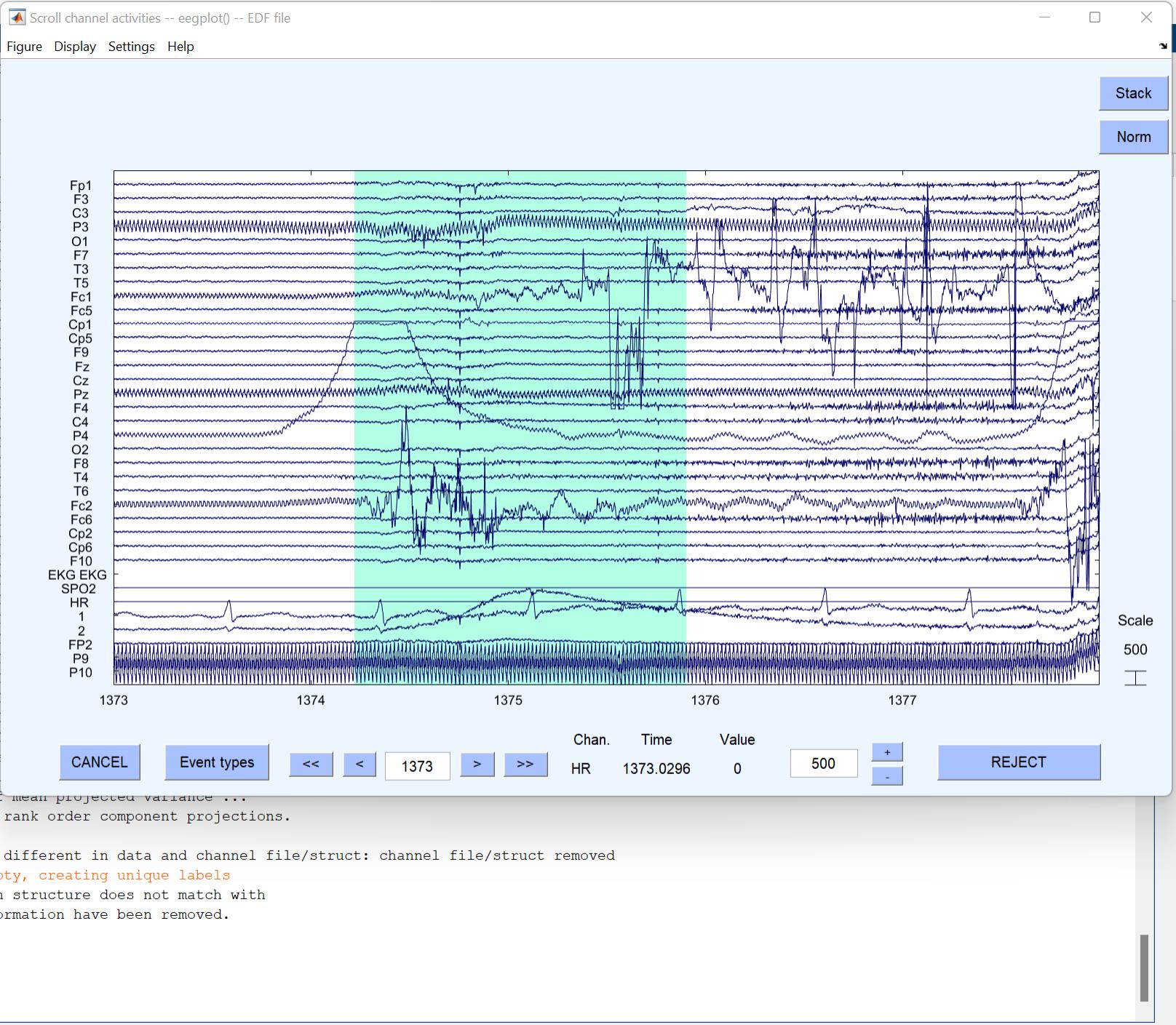
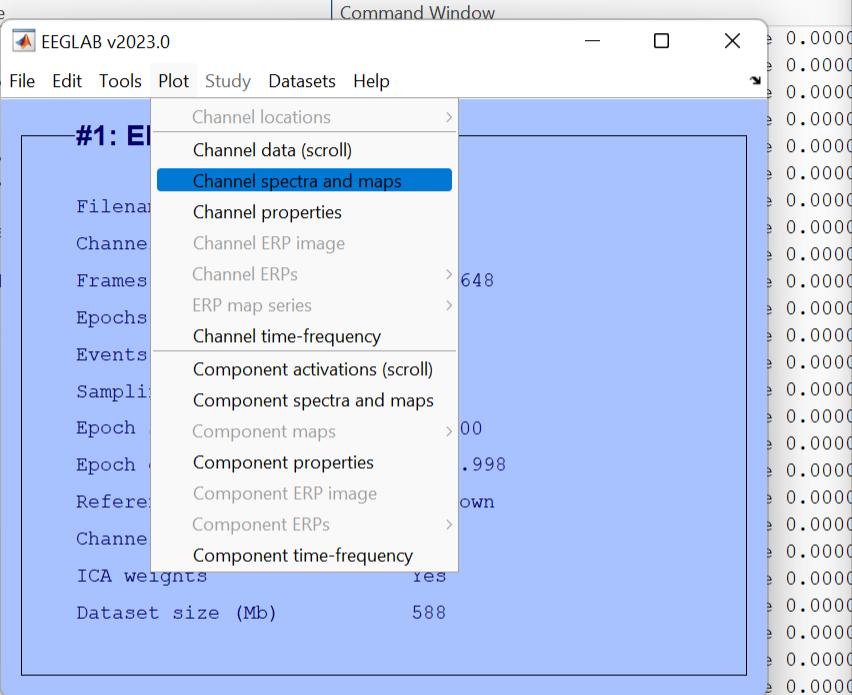
step 352 - lrate 0.000000, wchange 0.000000
step 353 - lrate 0.000000, wchange 0.000000
step 354 - lrate 0.000000, wchange 0.000000
step 355 - lrate 0.000000, wchange 0.000000
step 356 - lrate 0.000000, wchange 0.000000
Composing the eigenvector, weights, and s...
    into a single rectangular weights matrix; sphere=eye(34)
Sorting components in descending order of mean projected variance ...
Using pseudo-inverse of weight matrix to rank order component projections.
Scaling components to RMS microvolt
eeg_checkset warning: number of channels different in data and channel file/struct: channel file/struct removed
Warning: channel labels should not be empty, creating unique labels
Warning: the size of the channel location structure does not match with
    number of channels. Channel information have been removed.
Scaling components to RMS microvolt
Scaling components to RMS microvolt
Done.

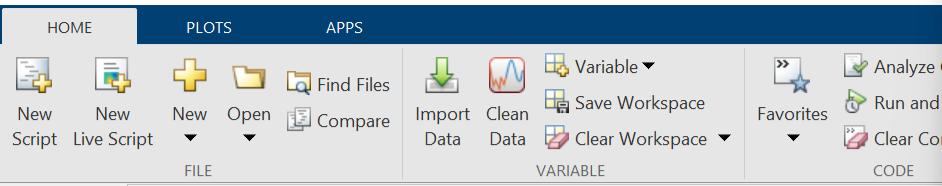
```





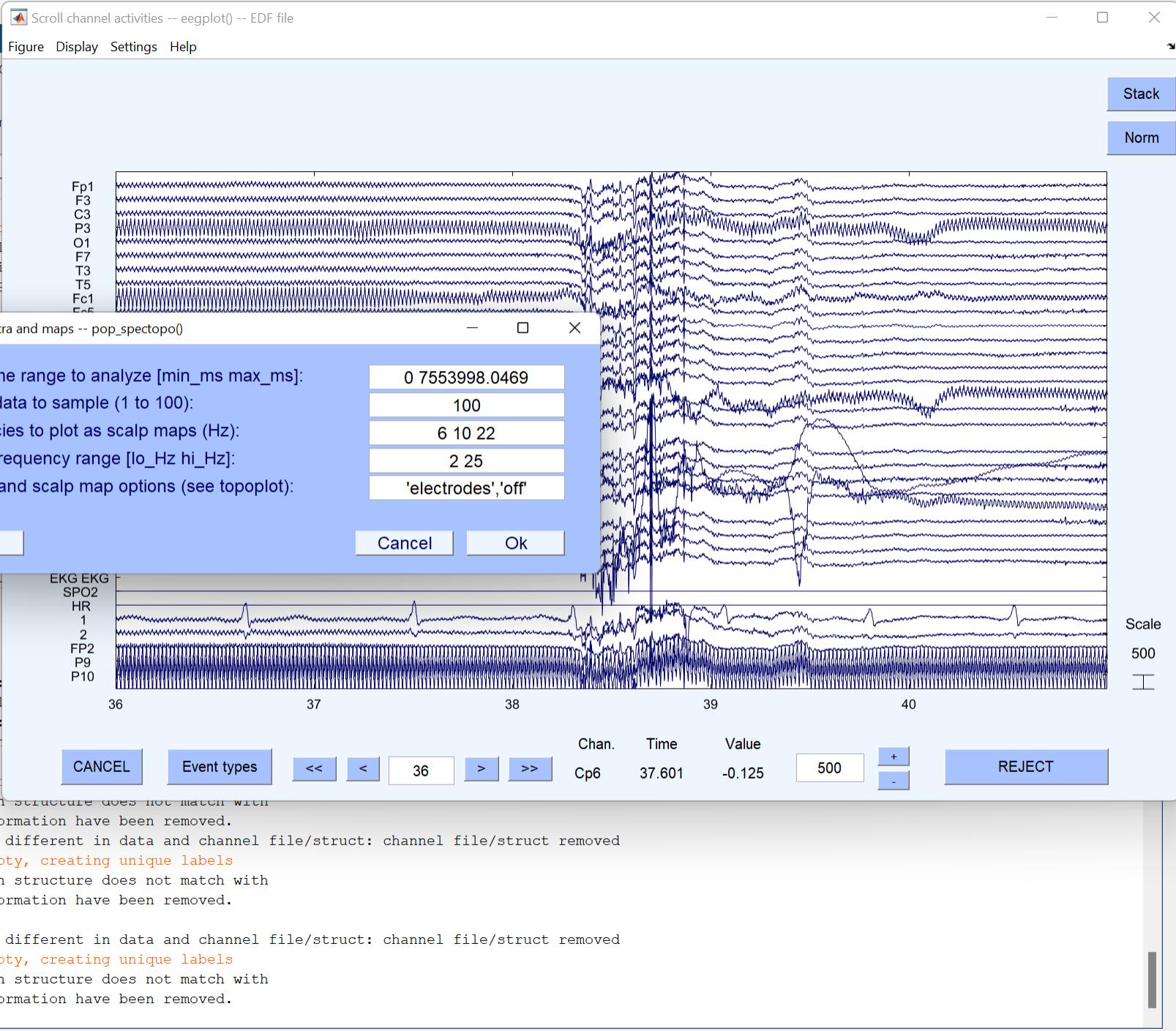
C: > Users > ASUS > Downloads >





C: > Users > ASUS > Downloads >

Workspace		Command Window
Name	Value	
ALLCOM	1x21 cell	to convert between channel location
ALLEEG	1x1 struct	Warning: channel labels should not be empty
ans		readlocs(): 'loc' format assumed from file
EEGLAB v2023.0		and in E1, LPA, RE



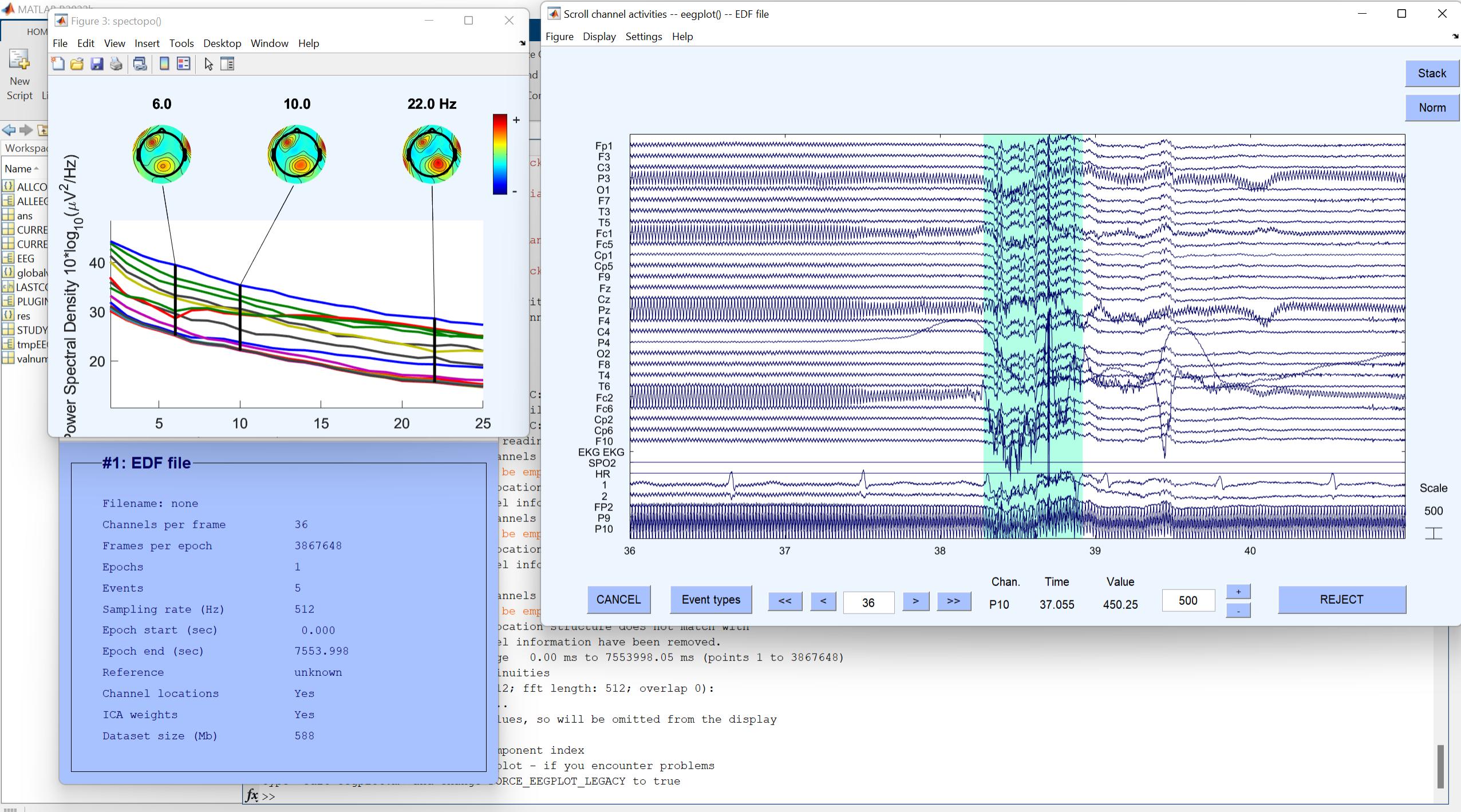
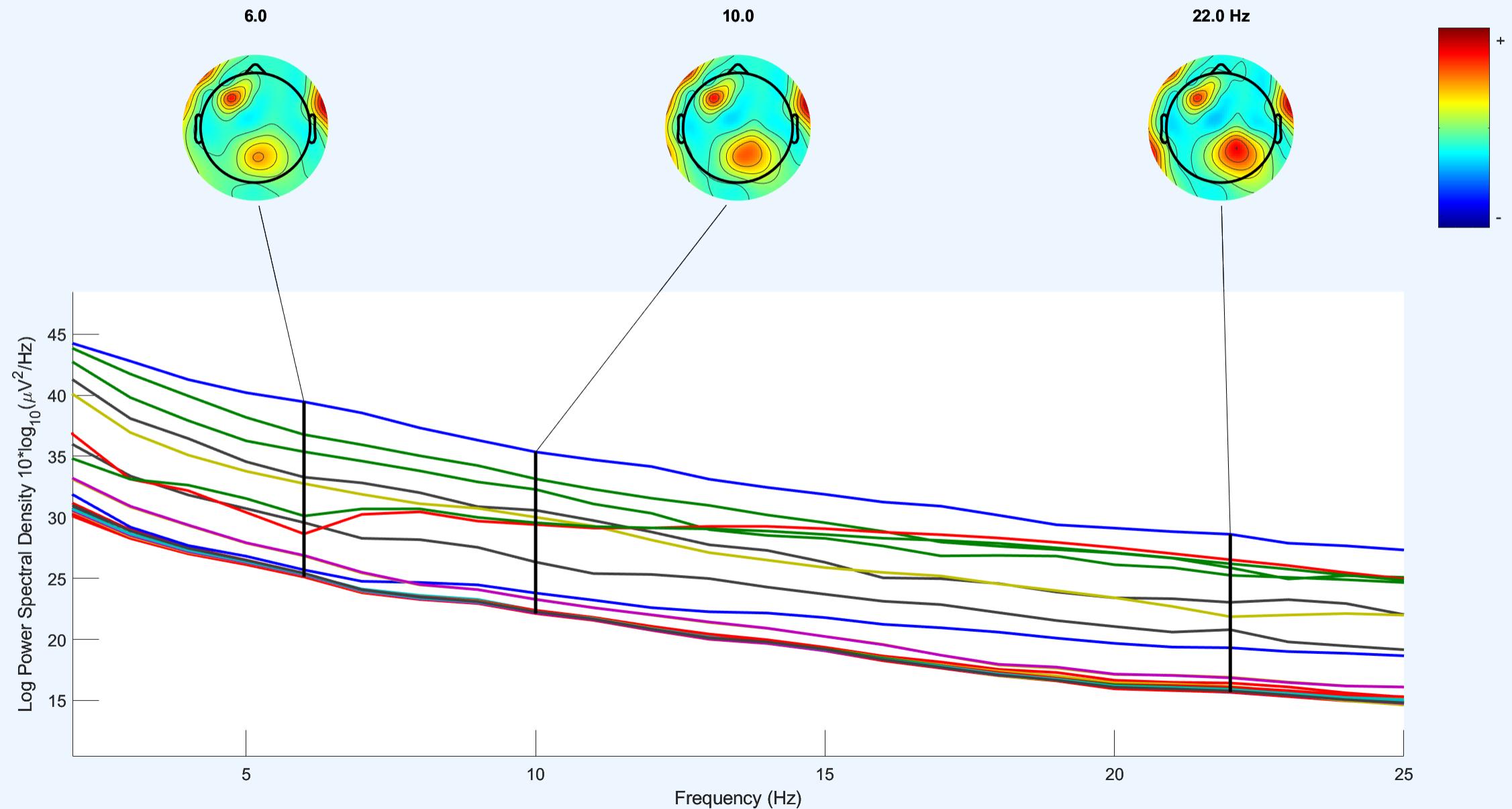


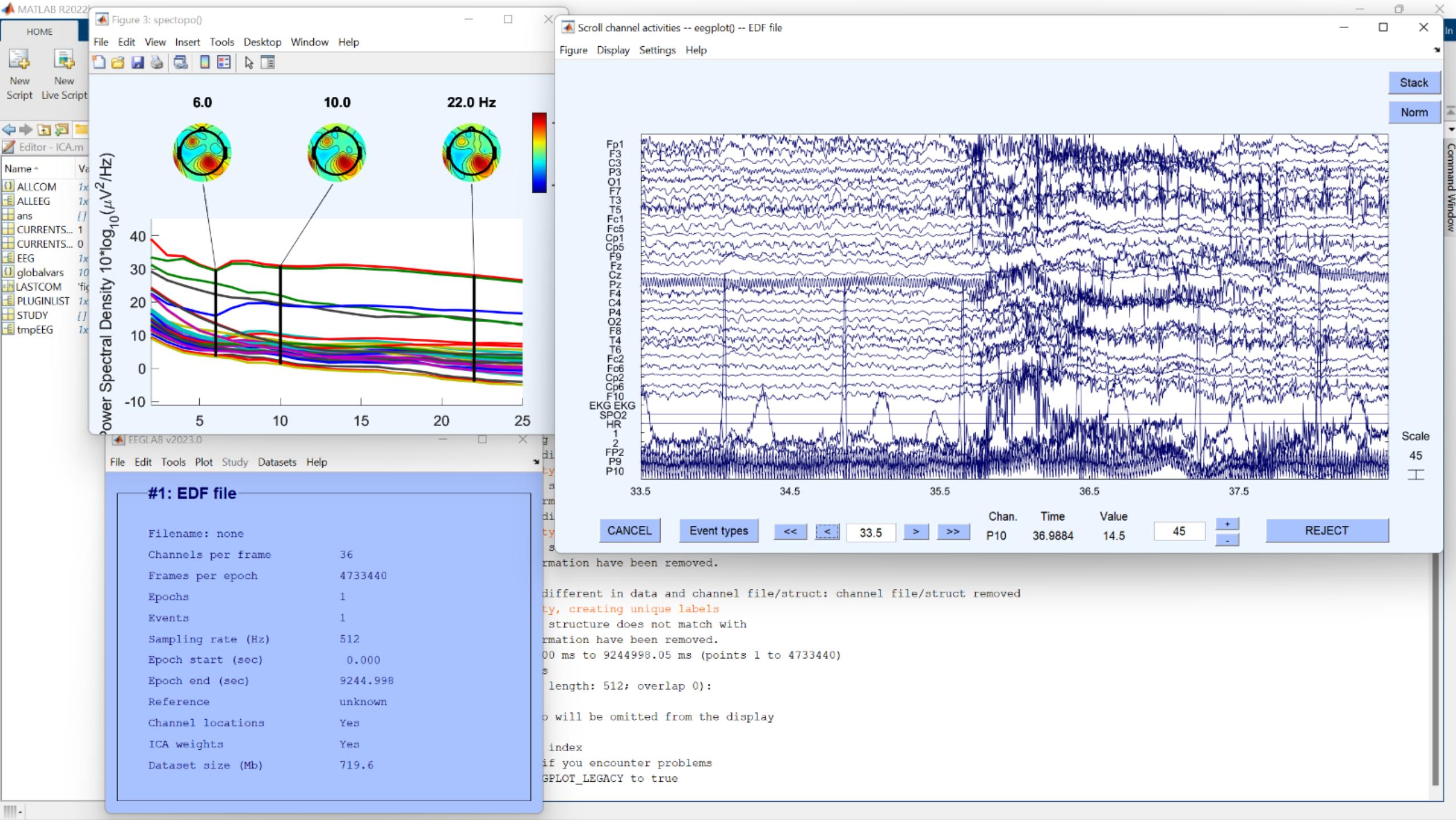
Figure 3: spectopo()

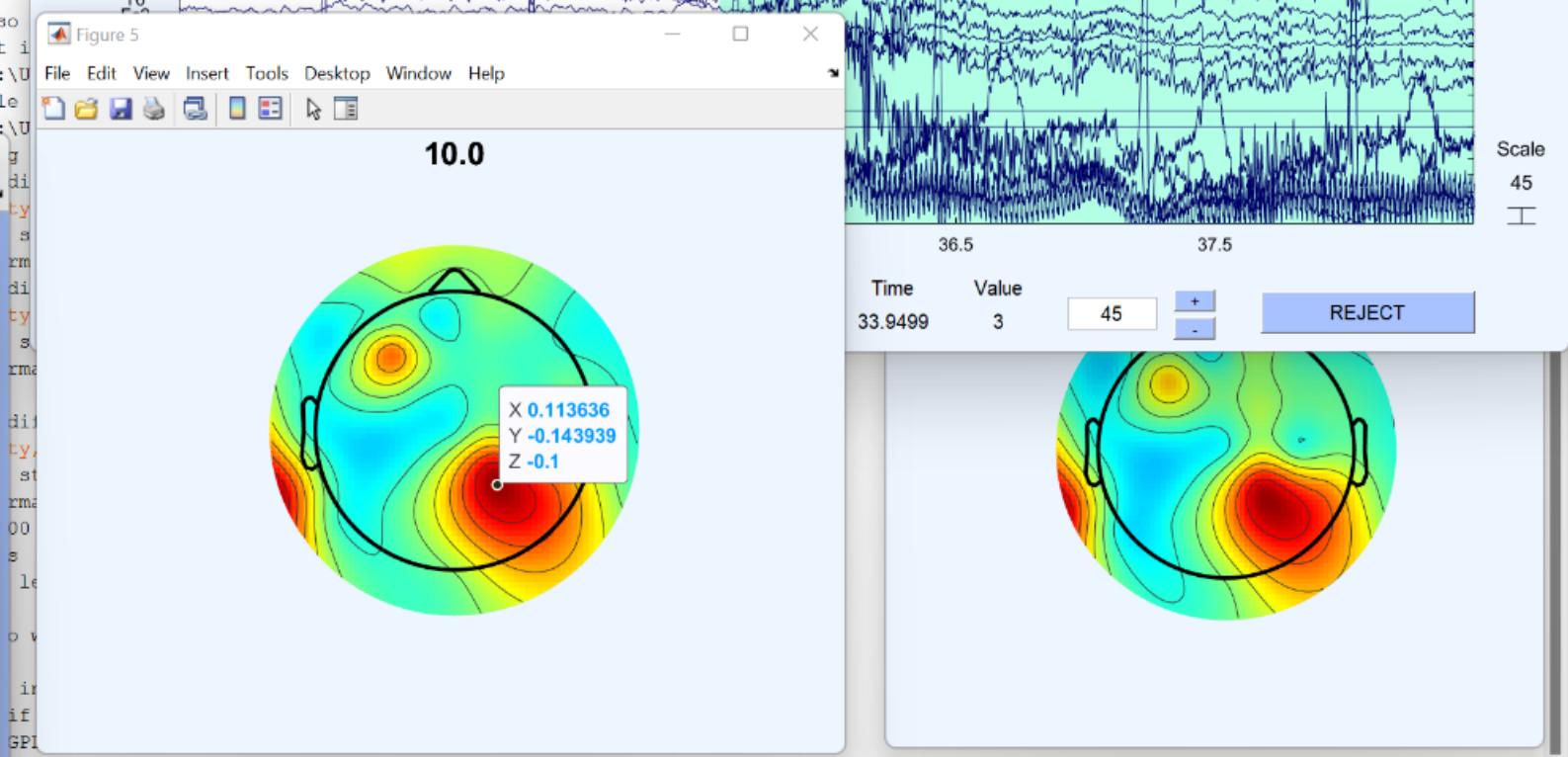
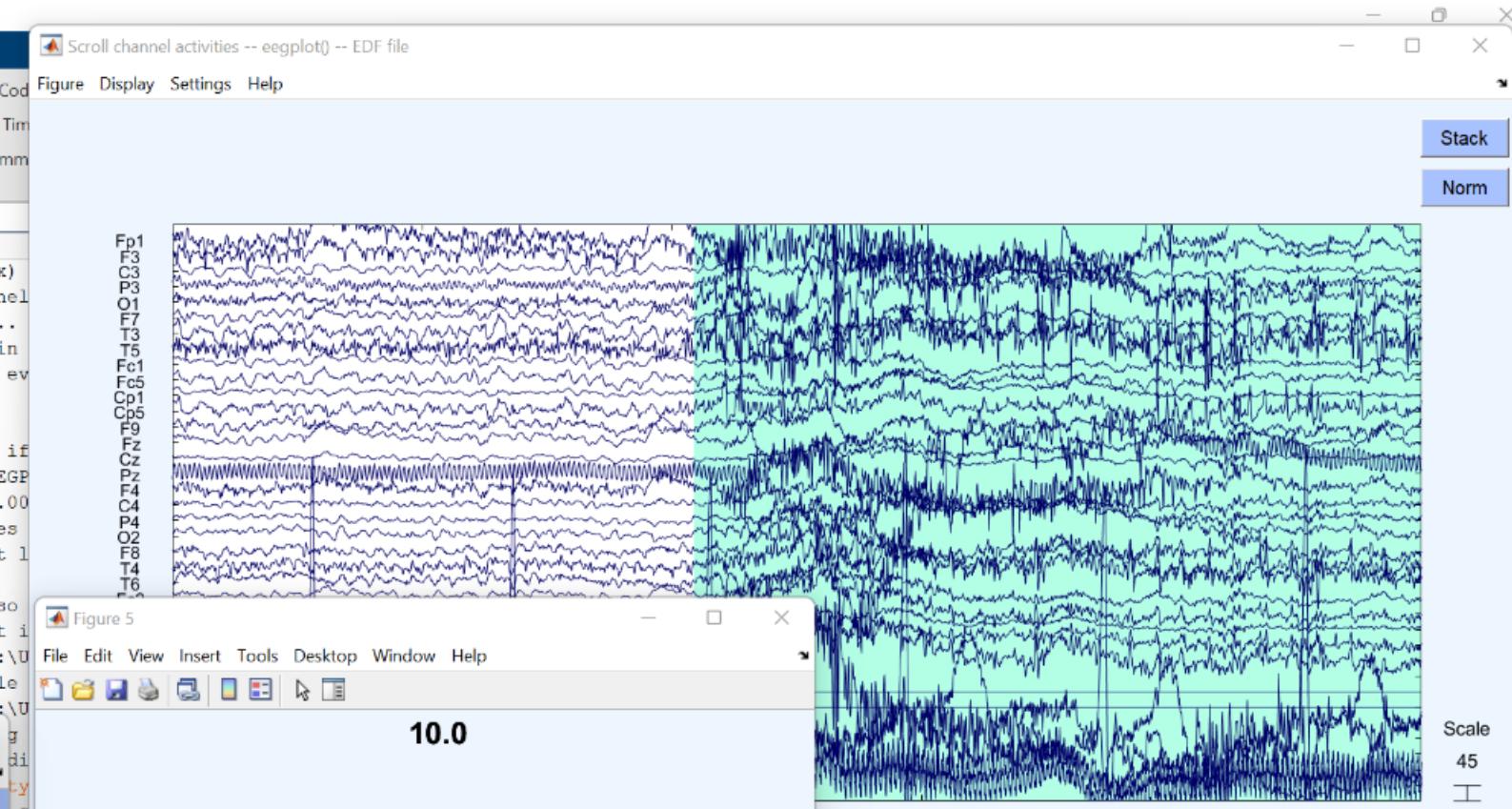
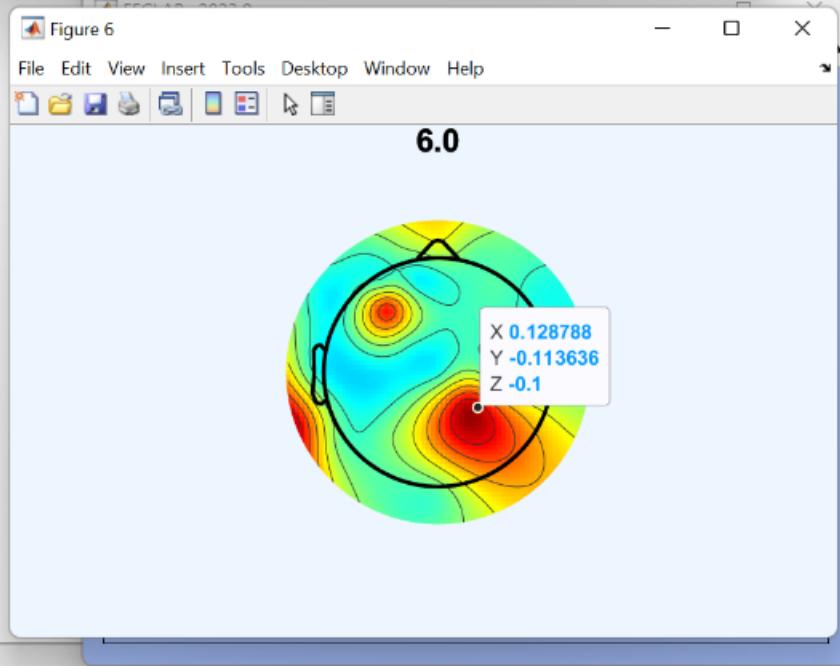
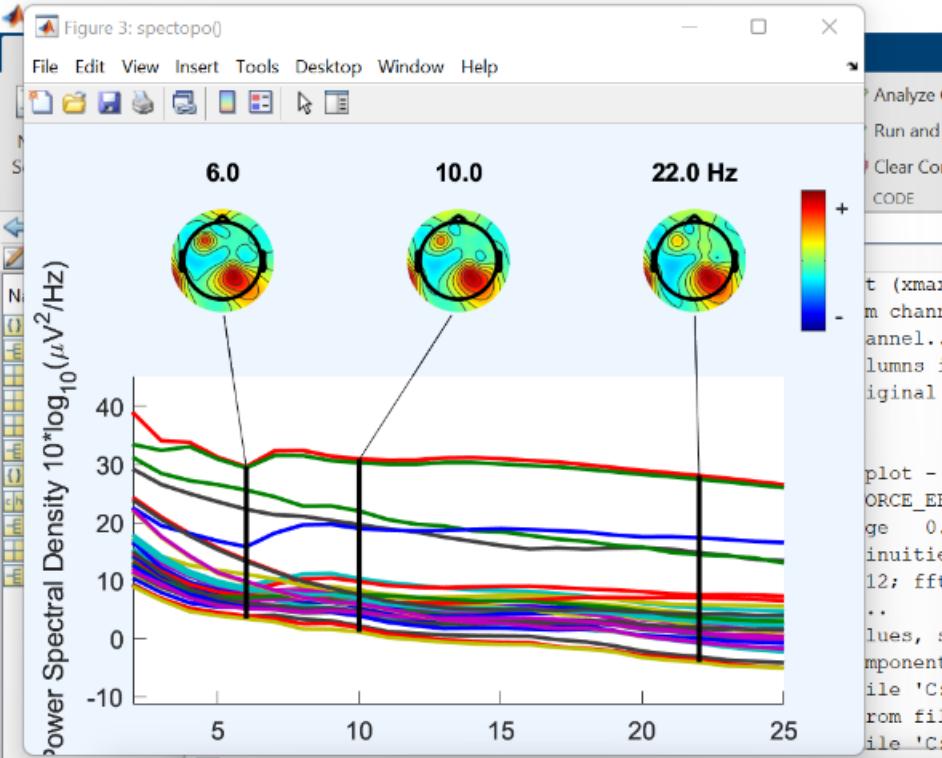
File Edit View Insert Tools Desktop Window Help

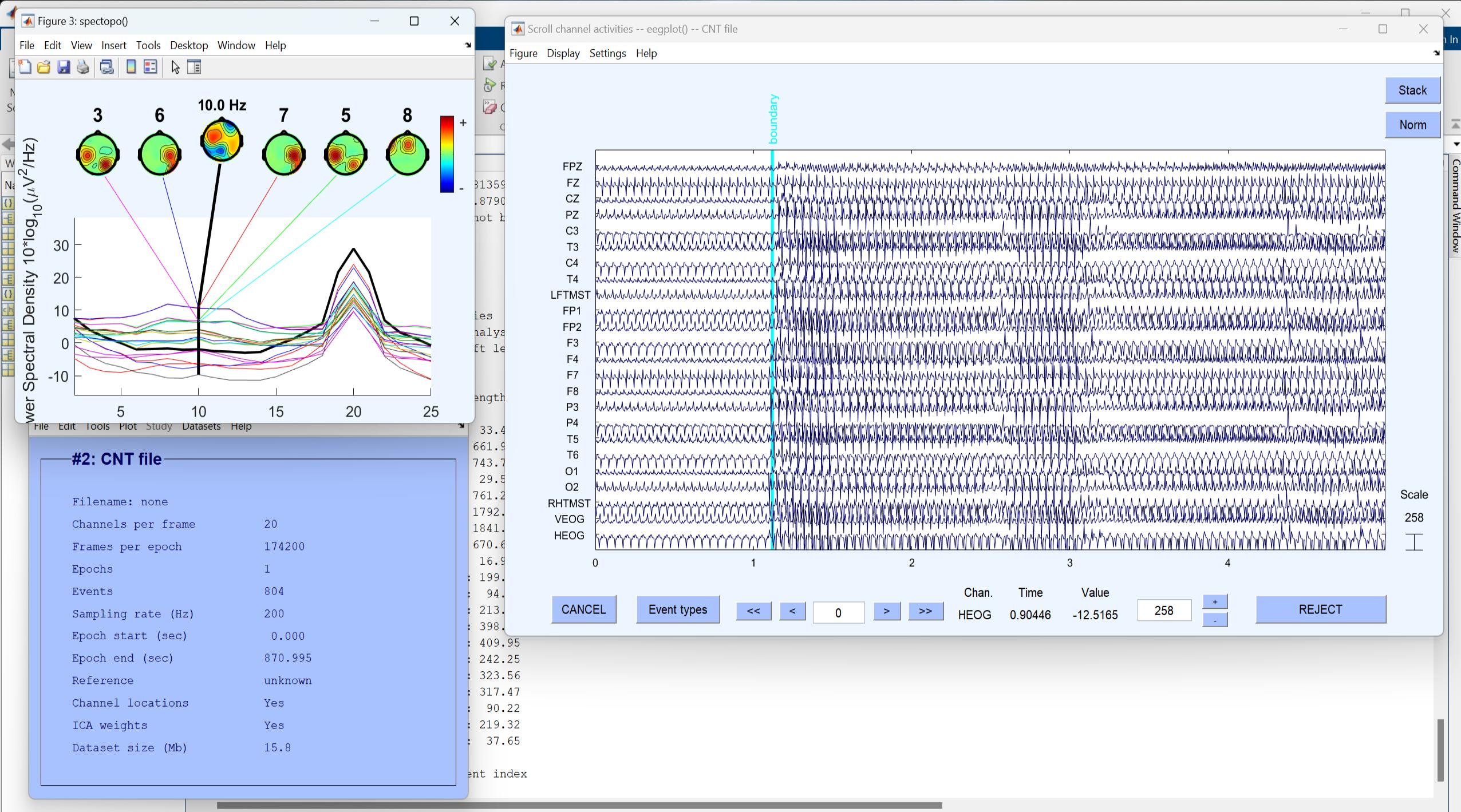


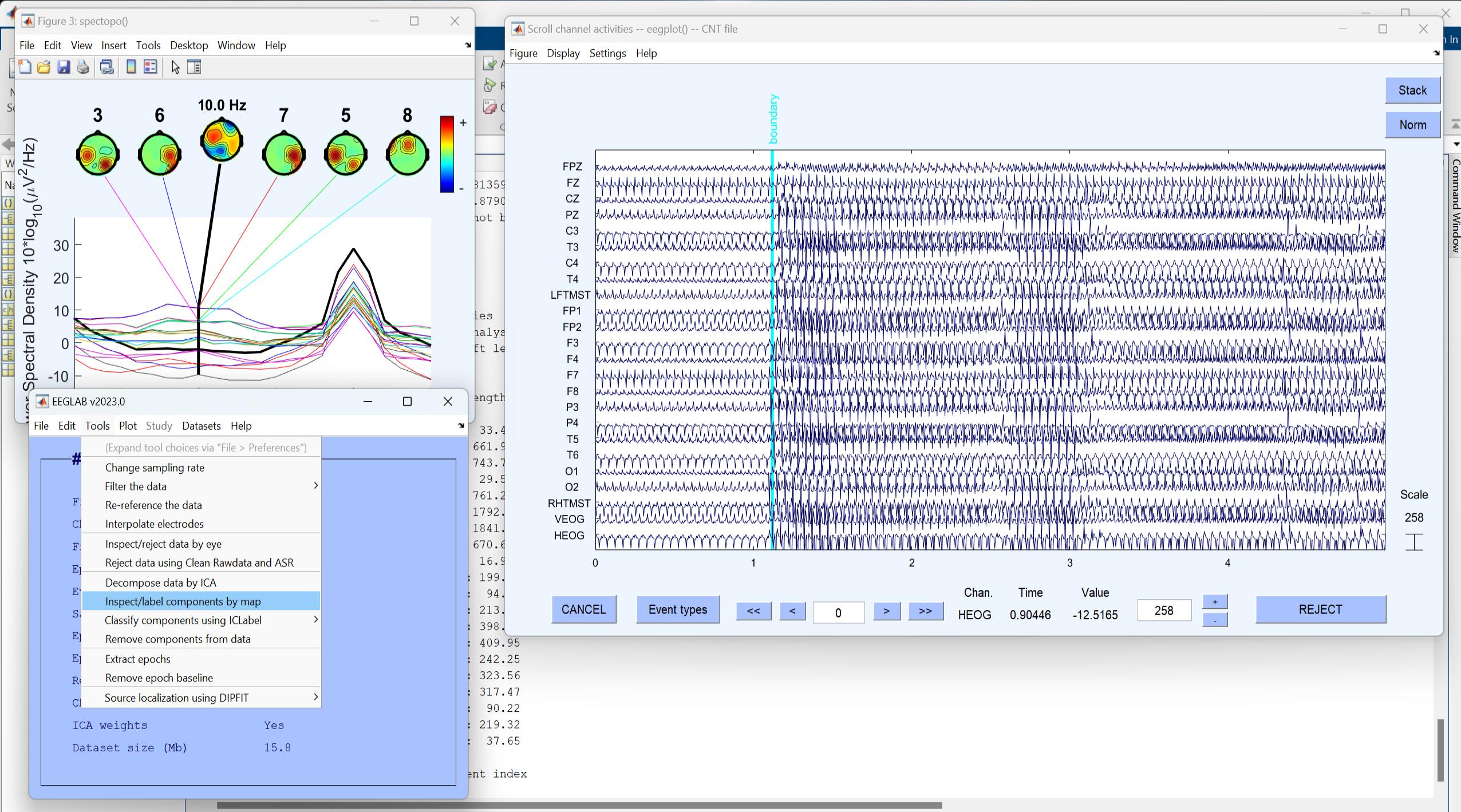
- □ X

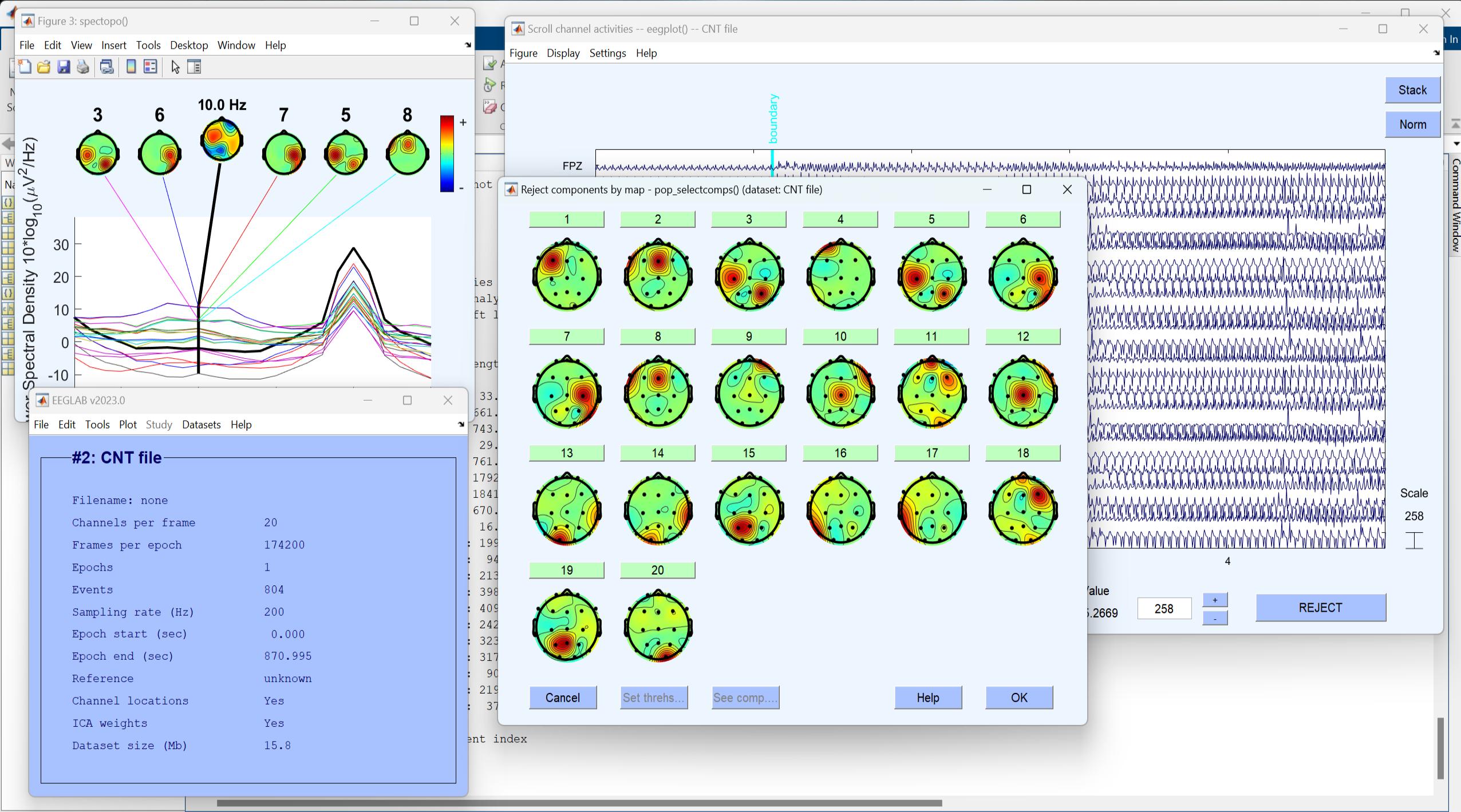


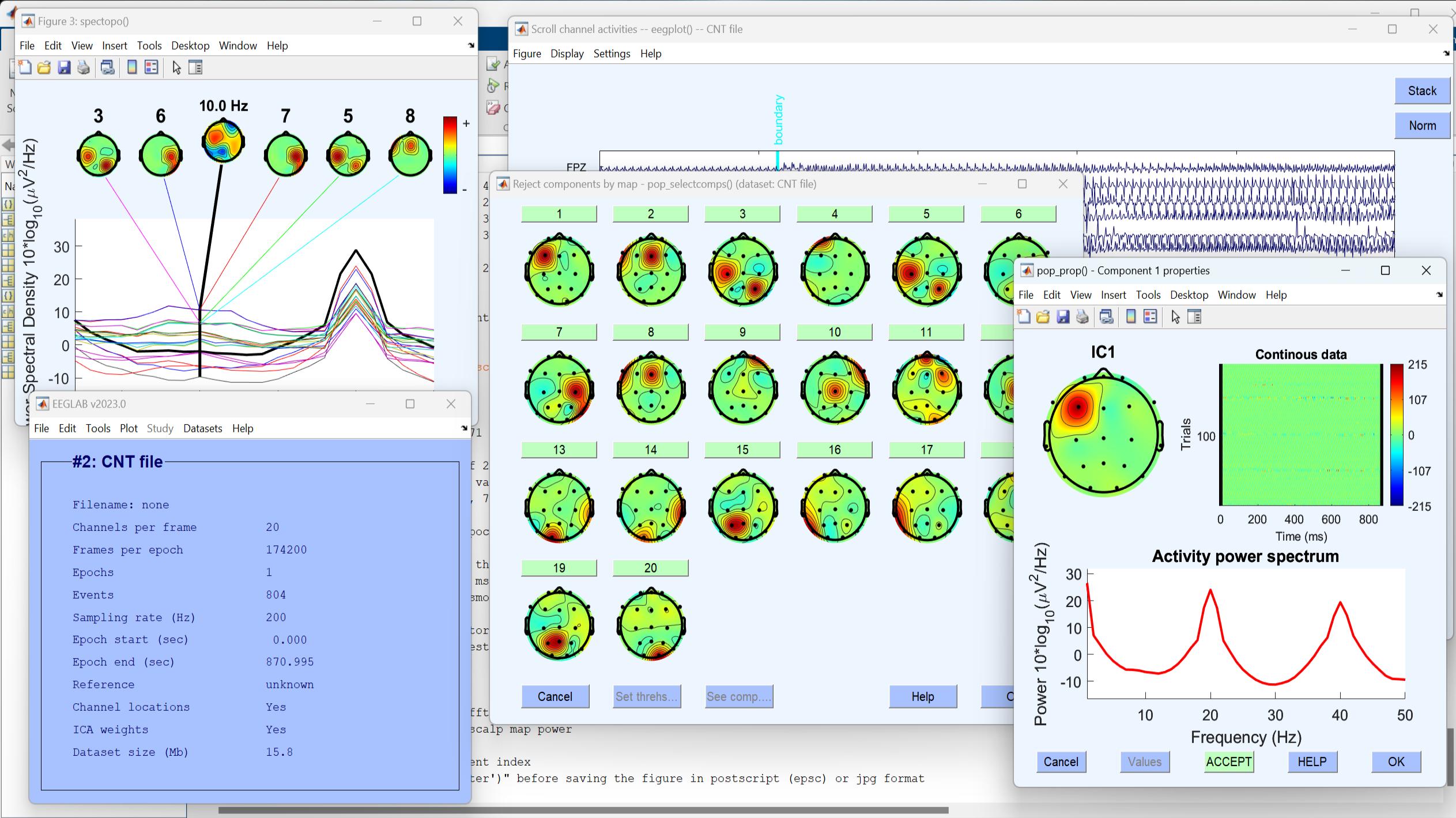


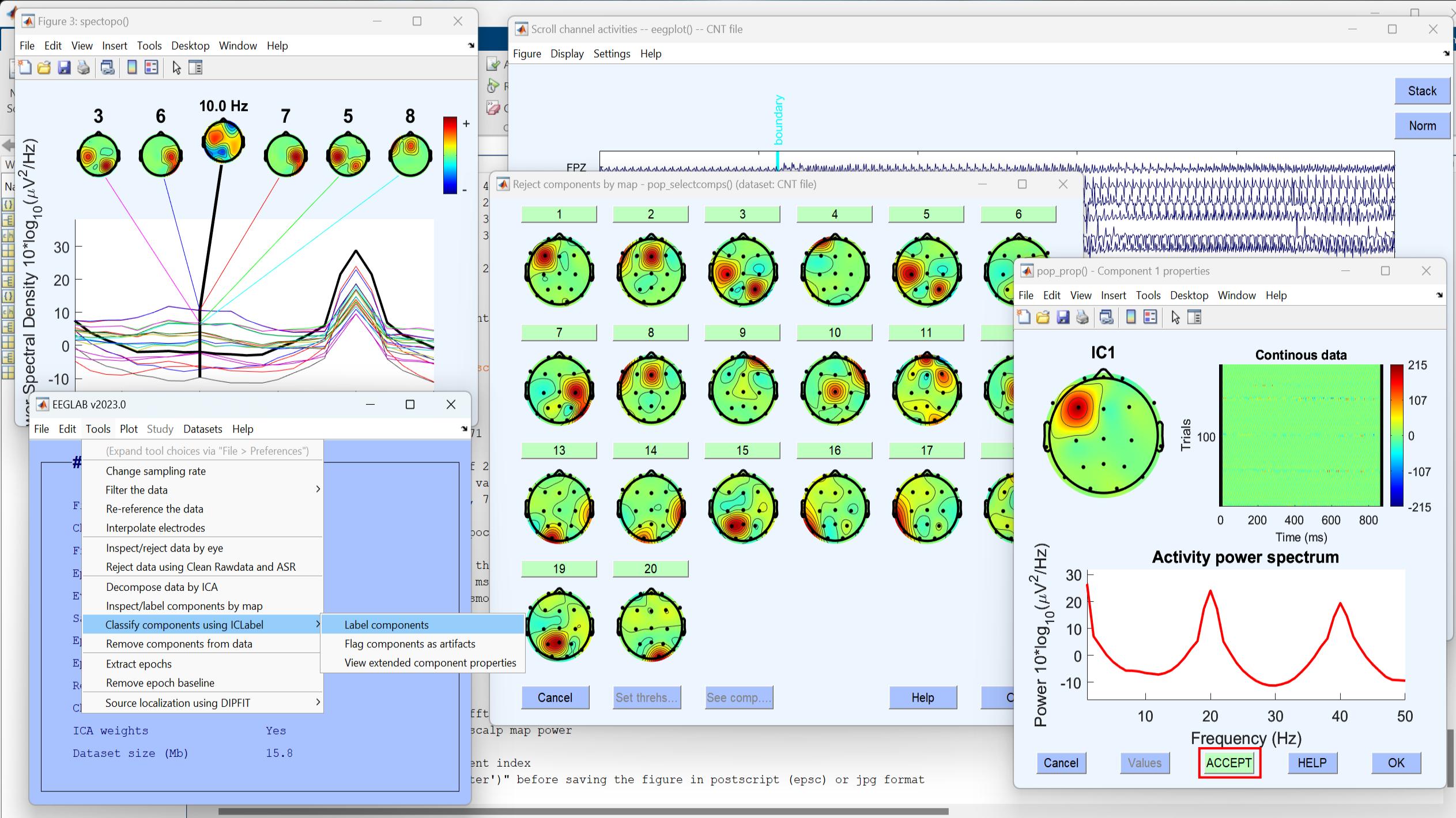


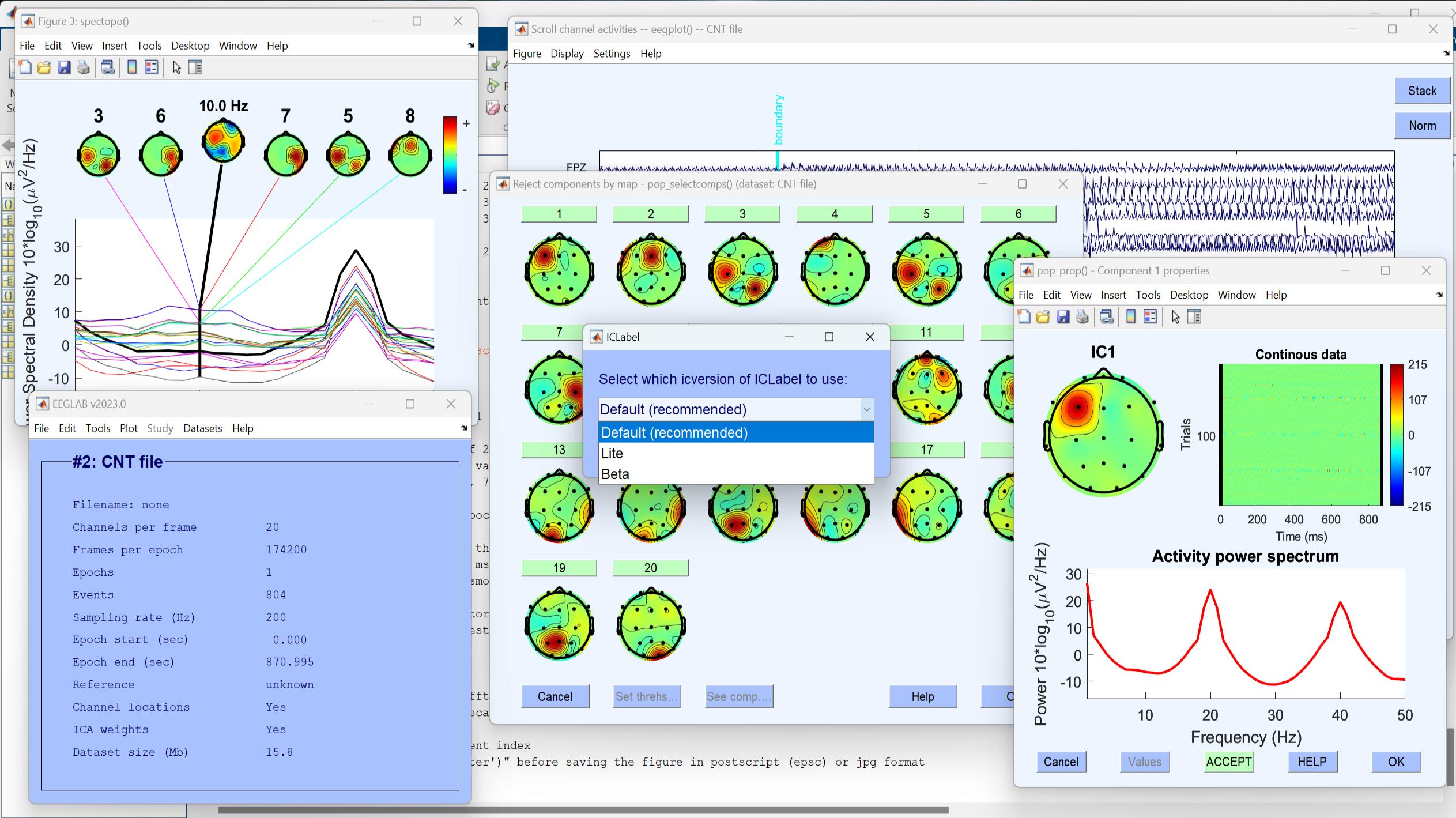




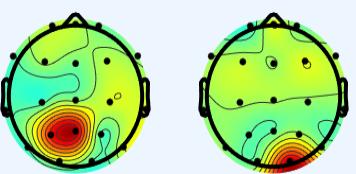
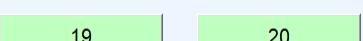
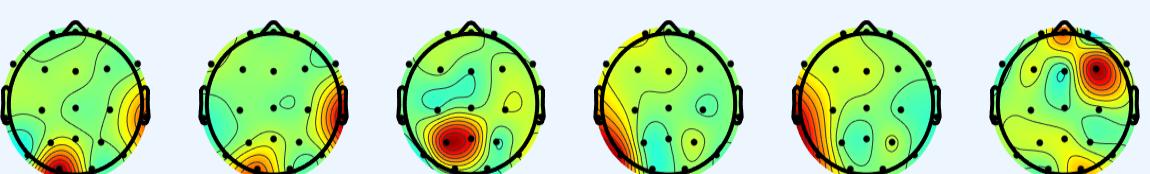
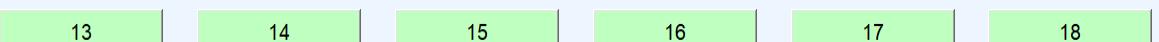
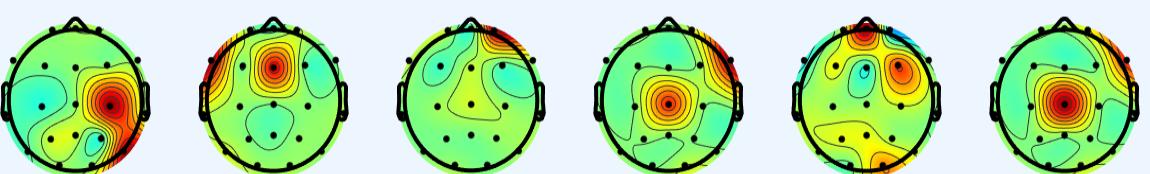
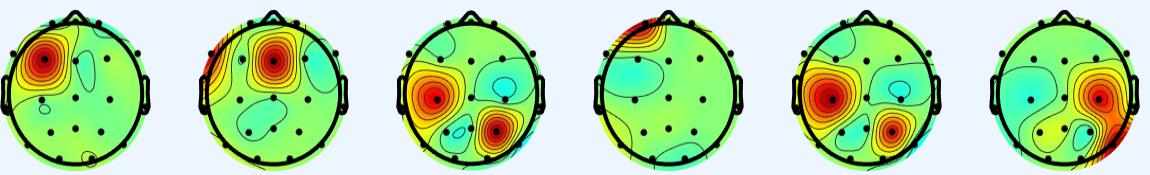
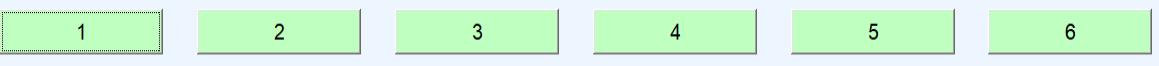








Reject components by map - pop_selectcomps() (dataset: CNT file)



Cancel

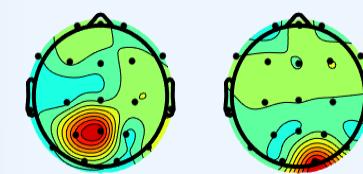
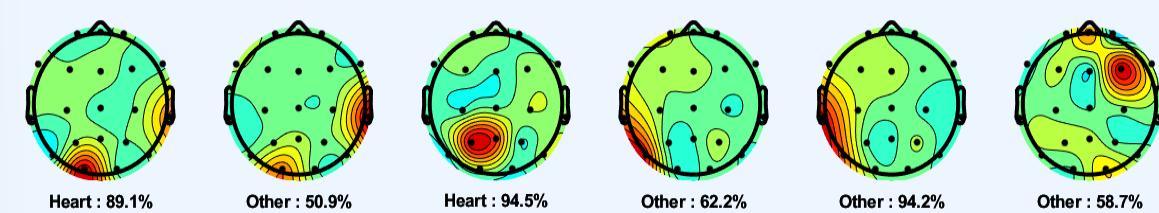
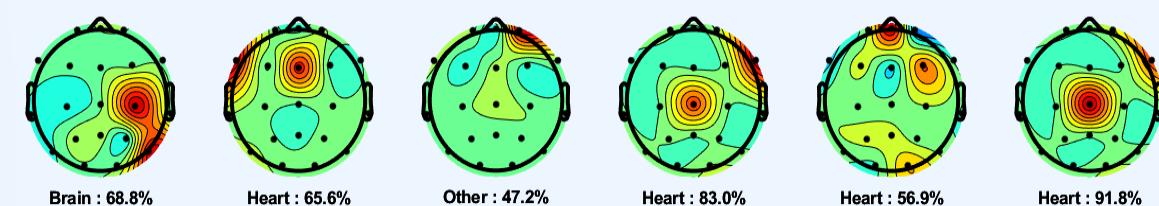
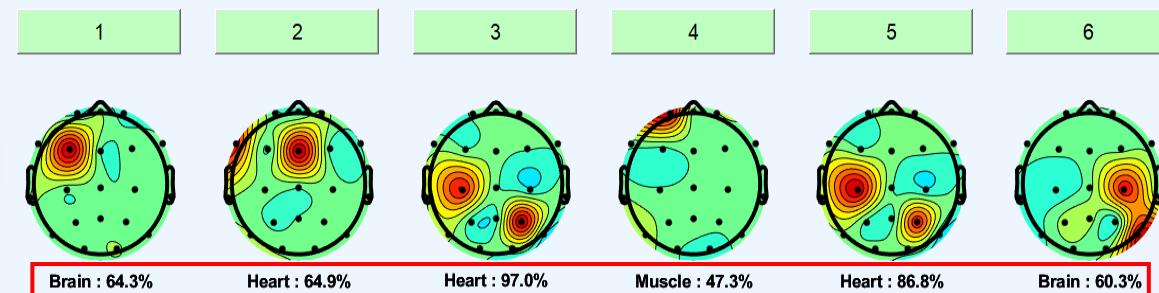
Set threhsolds

See comp. stats

Help

OK

View components properties - pop_viewprops() (dataset: CNT file)



Butterworth Filter

```
Butterworth_Filter.m +  
1 fs = 100; % Sampling frequency (Hz)  
2 t = 0:1/fs:1; % Period (s)  
3 f = 1; % Signal frequency (Hz)  
4 A = 1; % The maximum value of the signal  
5  
6 %% Signal construction  
7 x = A*sin(2*pi*f*t);  
8  
9 %% Apply noise  
10 SNR = 10; % Noise power to signal power (dB)  
11 y = awgn(x, SNR, 'measured');  
12  
13 %% Apply the Butterworth filter  
14 fc = 0.2; % Filter cutoff frequency  
15 [b,a] = butter(6, fc/(fs/2));  
16 z = filter(b, a, y);  
17  
18 %% Display the signals  
19 figure;  
20 subplot(3,1,1);  
21 plot(t,x);  
22 title('Original Signal');  
23 xlabel('Time (s)');  
24 ylabel('Amount');  
25  
26 subplot(3,1,2);  
27 plot(t,y);  
28 title('Noisy Signal');  
29 xlabel('Time (s)');  
30 ylabel('Amount');  
31  
32 subplot(3,1,3);  
33 plot(t,z);  
34 title('The signal after applying the Butterworth filter');  
35 xlabel('Time (s)');  
36 ylabel('Amount');
```

To make a signal in MATLAB, you can use internal MATLAB functions such as Sin, Cos, Sawtooth, etc.

To apply noise to the signal, the awgn function can be used.

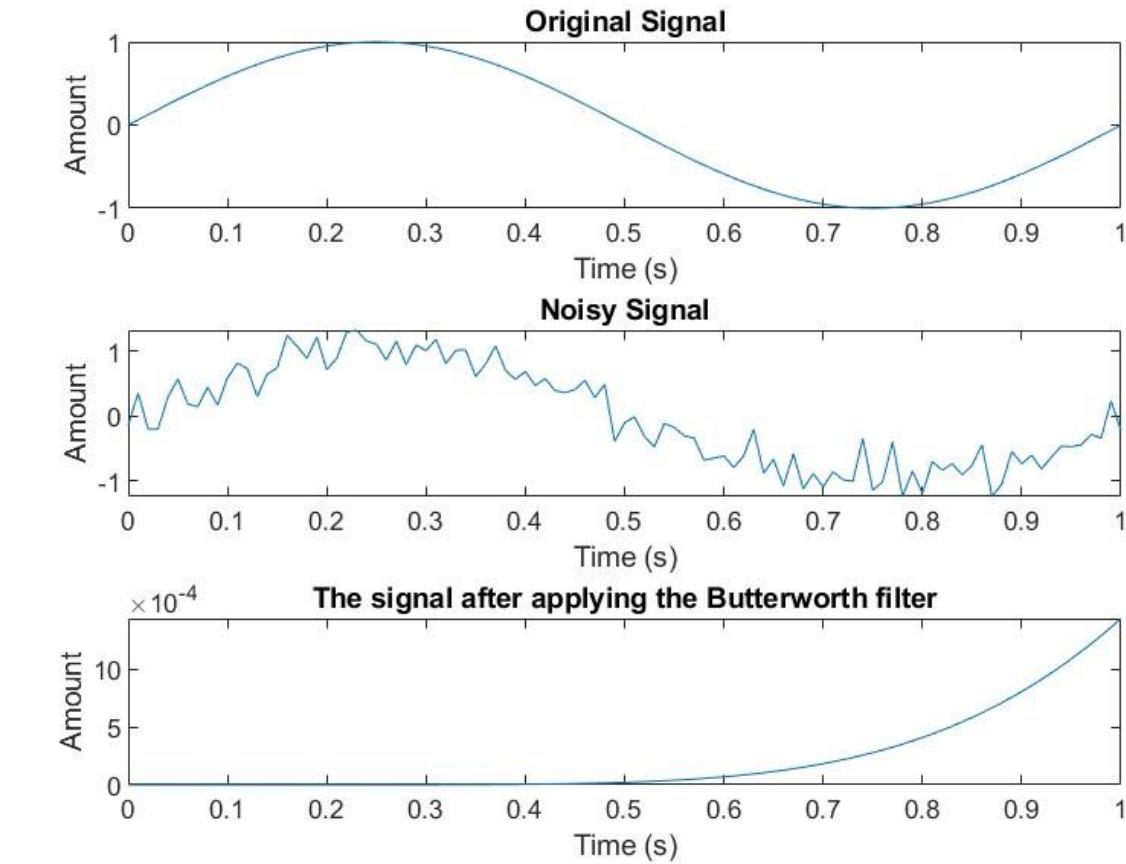
To apply the Butterworth filter, you can use the butter function.

First, we set the signal generation parameters and then we create the signal with a frequency of 1 Hz. Then noise with power

We apply $\text{SNR} = 10\text{dB}$ to our signal and finally Butterworth filter with cutoff frequency $f_c = 0.2\text{Hz}$ to

We add our signal.

Butterworth Filter Output



Elliptic Filter

```
Elliptic_Filter.m +  
1 fs = 1000; % sampling frequency (Hz)  
2 t = 0:1/fs:1-1/fs; % time axis  
3 f = 10; % signal frequency (Hz)  
4 x = sin(2*pi*f*t); % Making signal with frequency f  
5  
6 %% applying noise to the signal  
7 SNR = 10; % signal to noise ratio (dB)  
8 noise = randn(size(x)); % noise generation with Gaussian distribution  
9 noise = noise / norm(noise) * norm(x) / (10^(SNR/20)); % Comparison of noise and signal energy based on SNR  
10 x_noisy = x + noise; % Adding noise to the signal  
11  
12 %% Apply elliptic filter  
13 [n, Wn] = ellipord(40/100, 50/100, 3, 30); % Calculation of degree and filter coefficients  
14 [b, a] = ellip(n, 3, 30, 40/100); % Elliptic filter design  
15 freqz(b,a)  
16 x_filtered = filter(b, a, x_noisy); % Apply filter on noisy signal  
17  
18 %% Show the main signal, noisy signal and signal after filter application  
19 figure  
20 subplot(3,1,1);  
21 plot(t,x);  
22 title('main signal');  
23 xlabel('Time (s)');  
24 ylabel('Amplitude');  
25  
26 subplot(3,1,2);  
27 plot(t,x_noisy);  
28 title('Noisy signal');  
29 xlabel('Time (s)');  
30 ylabel('Amplitude');  
31  
32 subplot(3,1,3);  
33 plot(x_filtered);  
34 title('signal after applying the filter');  
35 xlabel('Time (s)');  
36 ylabel('Amplitude');
```

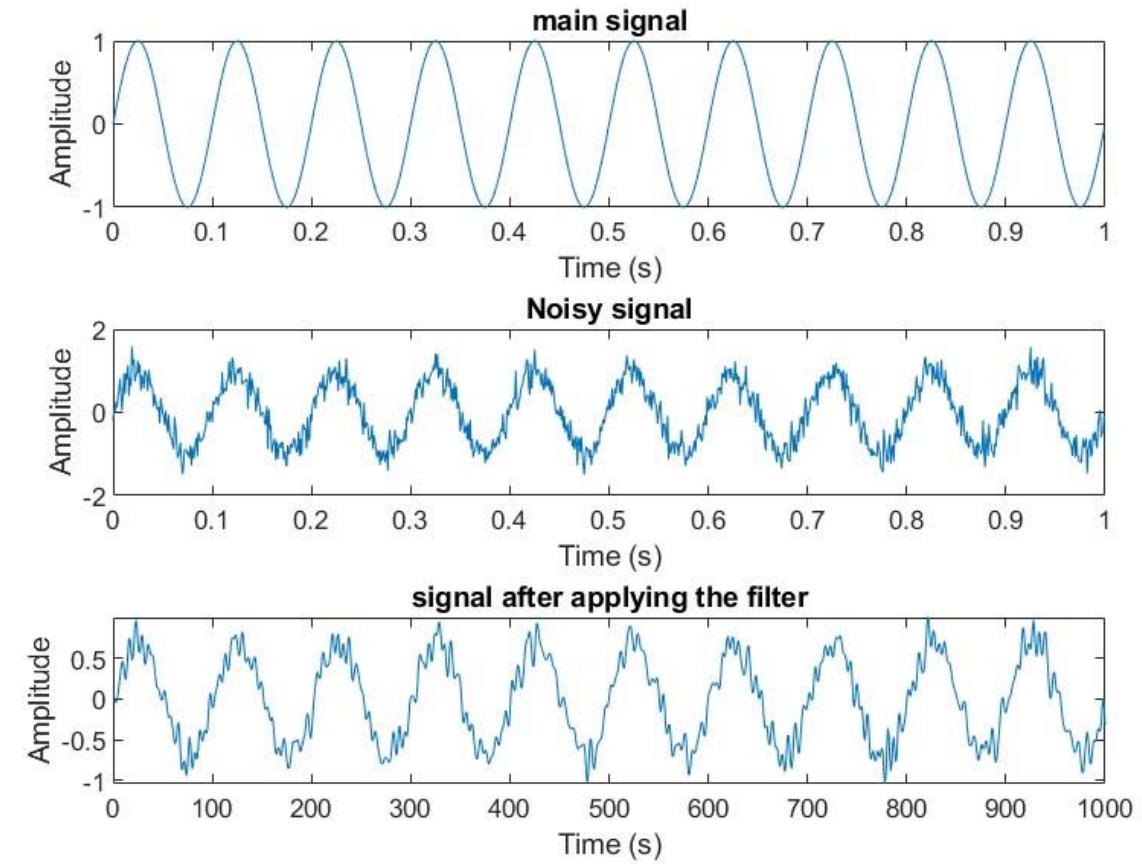
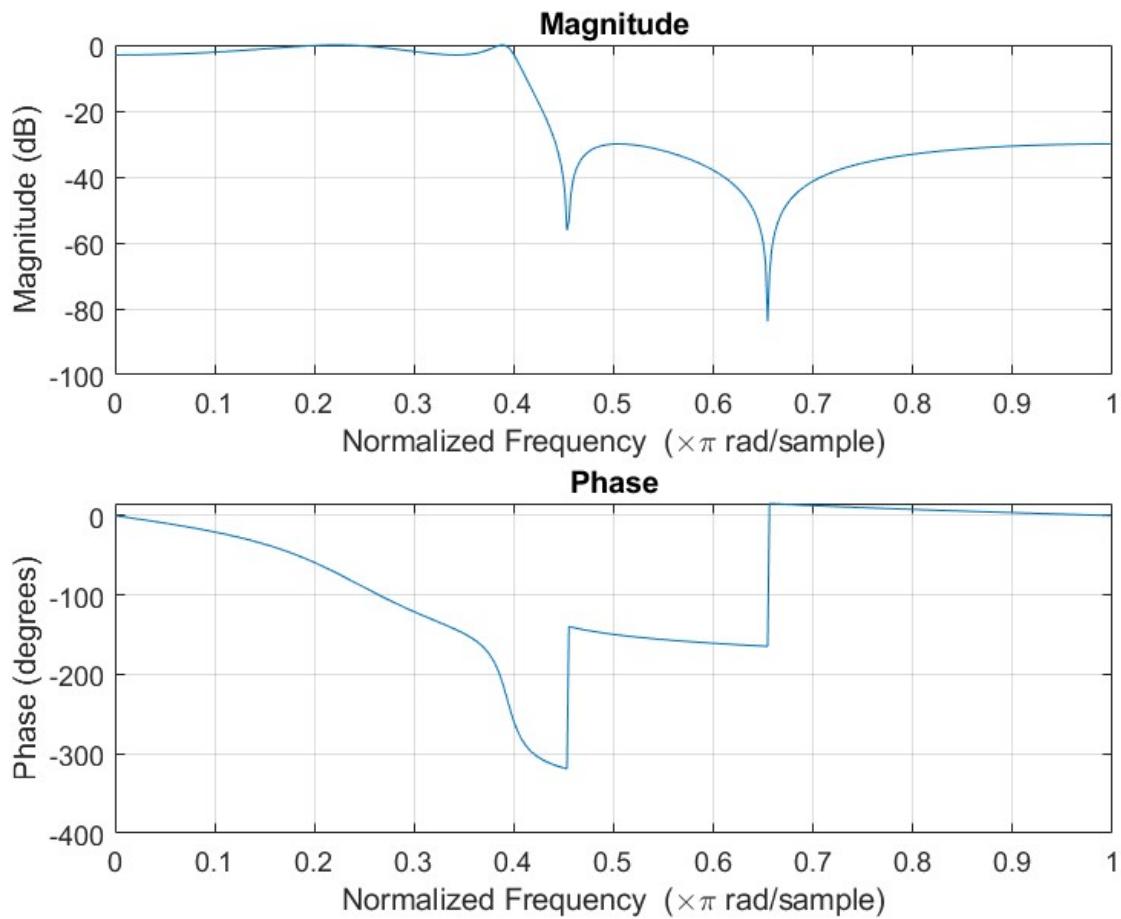
First, we design a signal with a sampling frequency of 1000 Hz and a signal frequency of 10 Hz.

Then we create a noise with Gaussian distribution and apply it to our signal.

Finally, we define the Elliptic filter parameters and apply them to our noise signal.

Then we display the signal in all three stages (main signal, noisy signal, signal after applying the filter) to see the changes.

Elliptic Filter Output



THE END