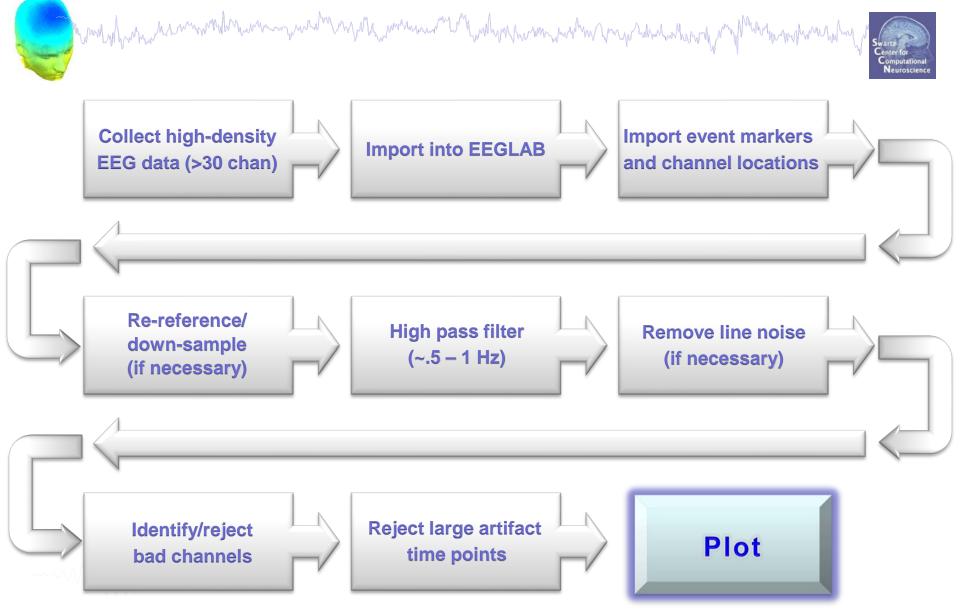


#### **Dense-array EEG**









# **EEGLAB Matlab toolbox**

hand have a provide and the second of the se

#### main graphic interface

** EEGLAB Shell - Konsole	$-\Box \times$
Session Edit View Bookmarks Settings Help	
	EEGLAB v5.03
/home/arno> matlab -nodesktop	File Edit Tools Plot Study Datasets Help
<pre>&lt; M A T L A B &gt; Copyright 1984-2002 The MathWorks, Inc. Version 6.5.0.180913a Release 13 Jun 18 2002 Using Toolbox Path Cache. Type "help toolbox_path_cache" for To get started, type one of these: helpwin, helpdesk, or demo. For product information, visit www.mathworks.com. &gt;&gt; eeglab</pre>	<ul> <li>No current dataset</li> <li>Create a new or load an existing dataset: Use "File &gt; Import data" (new) Or "File &gt; Load existing dataset" (old)</li> <li>If new, "File &gt; Import epoch info" (data epochs) else "File &gt; Import event info" (continuous data) "Edit &gt; Dataset info" (add/edit dataset info) "File &gt; Save dataset" (save dataset)</li> <li>Prune data: "Edit &gt; Select data"</li> <li>Reject data: "Tools &gt; Reject continuous</li> <li>Epoch data: "Tools &gt; Remove</li> <li>Run ICA: "Tools &gt; Run ICA"</li> </ul>
The folder with eeglab.m must be in your Matlab "paths"	- Kunica: Tools 2 Kunica

Ne

#### Importing a dataset



E	EGLAB v5.03
File Edit Tools Plot	Study Datasets Help
Import data	From ASCII/float file or Matlab arra
Import epoch info	From continuous or seg. EGL.RAW
Import event info	From Multiple seg. EGL.RAW files
Export	From BCI2000 ASCII file
Load existing dataset	From Snapmaster .SMA file
Save current dataset(s	From Neuroscan .CNT file
Save current dataset a	S From Neuroscan .EEG file
Clear dataset(s)	From ERPSS .RAW or .RDF file
Create study	From Biosemi .BDF file using BIOSIC
Load existing study	From other formats using BIOSIG
Save current study	From ANT EEProbe .CNT file
Save current study as	From ANT EEProbe .AVR file
Clear study	From Brain Vis. Rec. what file
Memory options	From Brain Vis. Rec
Save history	>
Quit	From CTF folder (MEG)
	From INStep .ASC file
	From Mayo .MEF files
	From 4D .m4d pdf file

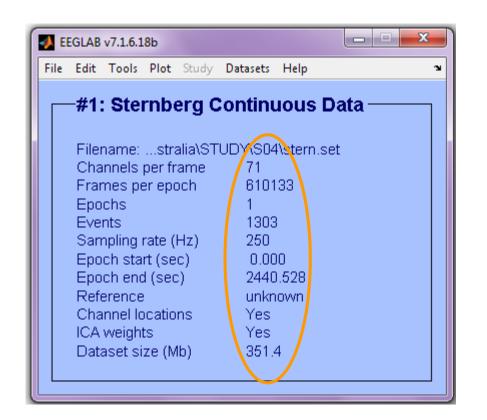
Troubleshooting, other data formats...

EEGLAB supports many different raw data formats

-----MMM...--

# **Imported EEG data**





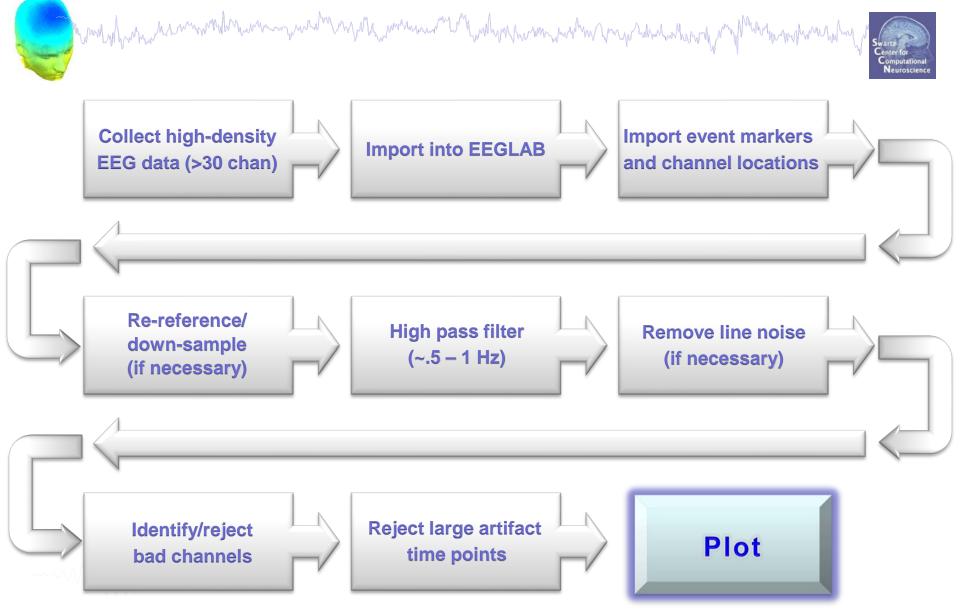
EEGLAB GUI displays dataset basics

#### Load an existing dataset

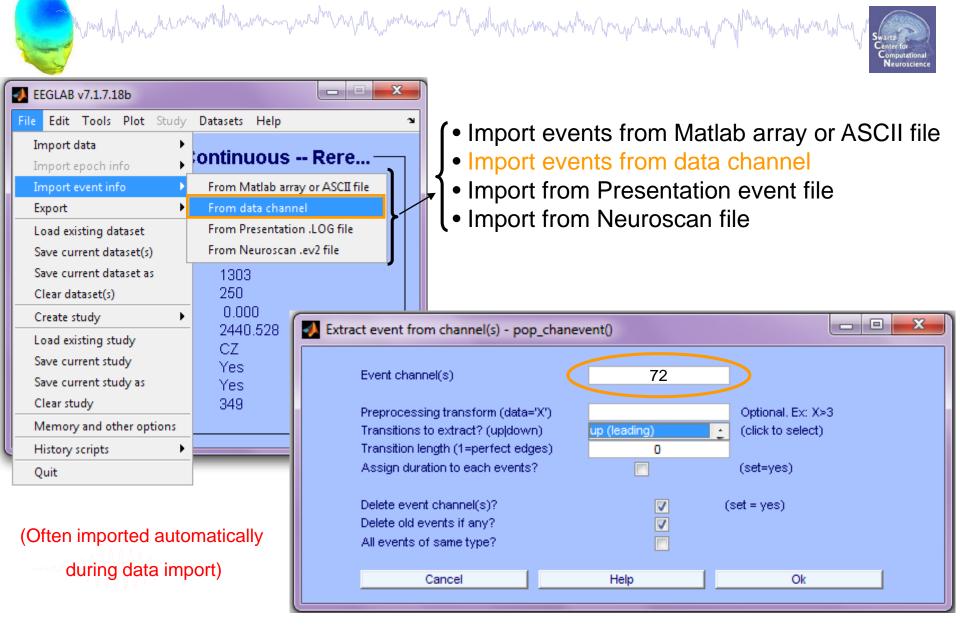
and have a second when a second when a second when a second of the secon



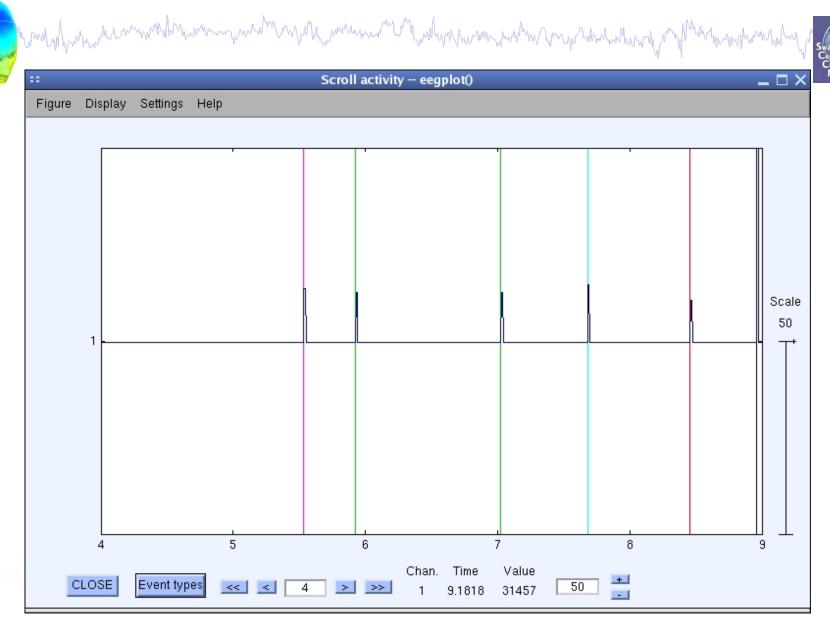
	ſ	🌗 Load dataset(s	s) pop_loadset()						<b></b> X
		Look in:	퉬 jo74		-	← 🗈 💣 📰 -			
		(Hai)	Name	*		Date modified	Туре		Size
EEGLAB v10.2.2.1b	Datasets Help	Recent Places	ignore.set	t		3/6/2009 8:29 AM 3/6/2009 1:09 PM	SET File SET File		120,589 KB 196,238 KB
Import data	set		probe.set			3/13/2009 7:29 AM 3/9/2009 4:40 PM	SET File SET File		68,307 KB 1,300 KB
Import epoch info	sei	Desktop	stern.set			3/9/2009 12:38 PM	SET File		1,500 KB 171,540 KB
Import event info	r load an existi oort data"	Libraries							
	d existing data								
Save current dataset(s)		Computer							
Nova current datacet ac	ooch info" (dat vent info" (conf								
	info" (add/edit	Network							
	aset" (save da								
	lit > Select dat		File name:	stem.set				•	Open
	ools > Reject		Files of type:	(*.SET*, *.set)				•	Cancel
Save current study as	ools > Extract			,					
Classification	ne: "Tools > Re ols > Run ICA"	move							
Memory and other options									
History scripts									
Quit									



#### Import data events

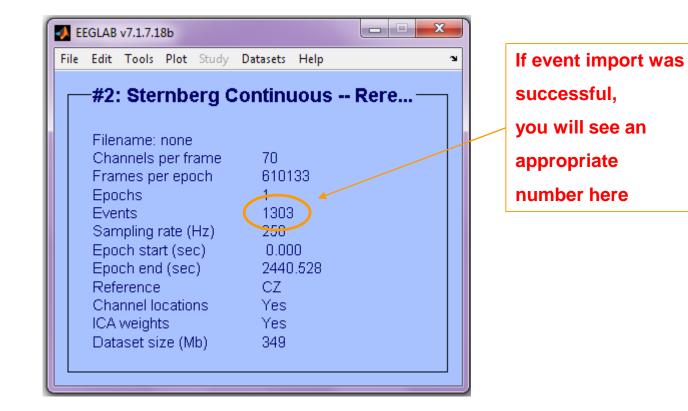


#### Appearance of an event channel in raw data

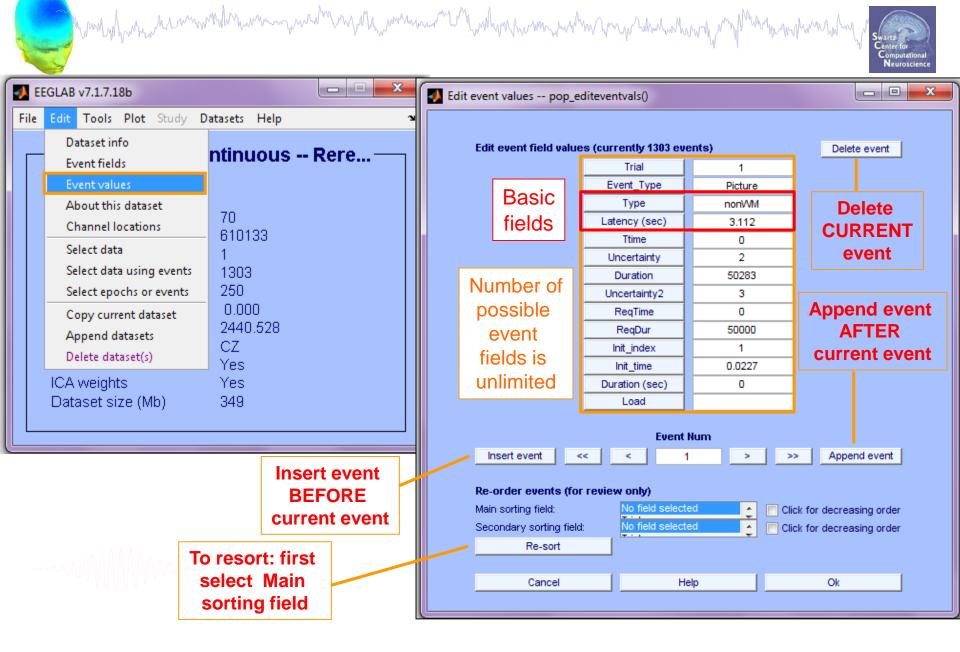


#### Imported data events





#### **Review event values**

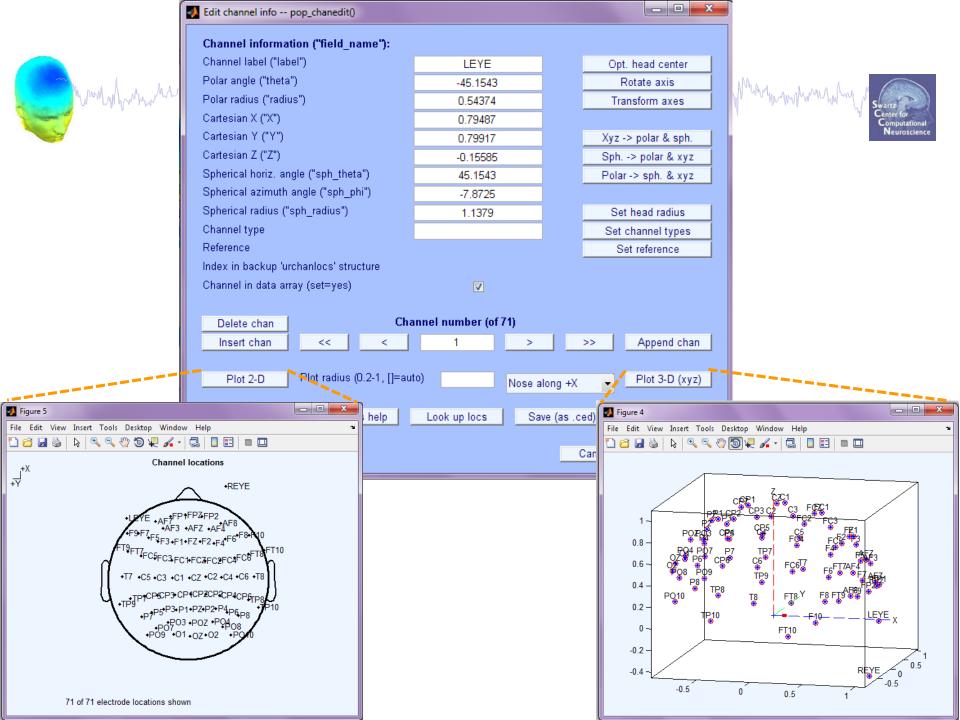


# **Import channel locations**

and the war the ward and the second	Edit channel info pop_chanedit()	
or officially server	Channel information ("field_name"):	r
	Channel label ("label")	Opt. head center
EEGLAB v10.2.2.1b	Polar angle ("theta")	Rotate axis
File Edit Tools Plot Study Datasets Help 🛥	Polar radius ("radius")	Transform axes
Dataset info IS	Cartesian X ("X")	
Event fields	Cartesian Y ("Y")	Xyz -> polar & sph.
Event values	Cartesian Z ("Z")	Sph> polar & xyz
About this dataset	Spherical horiz, angle ("sph_theta")	Polar -> sph. & xyz
Channel locations	Spherical azimuth angle ("sph_phi")	i olar v opri. de xyz
Select data	Spherical radius ("sph_radius")	Set head radius
Select data using events	Channel type	Set channel types
Select epochs or events	Reference	Set reference
Copy current dataset	Index in backup 'urchanlocs' structure	
Append datasets Delete dataset(s)		
Visually edit events and identify bad channels	Channel in data array (set=yes)	
Dataset size (Mb) 351.3	Channel annulas (-64)	
Dataset size (Mb) 551.5	Delete chan Channel number (of 1)	
	Insert chan << < 1 >	>> Append chan
	Plot 2-D Plot radius (0.2-1, []=auto) Nose along	+X  Plot 3-D (xyz)
9 file formats supported:		
['loc' 'sph' 'sfp' 'xyz' 'asc' 'polhe	Read locations Read locs help Look up locs Save (a	s.ced) Save (other types)
mus' 'besa' 'chanedit' 'custom']	Look up channel locations?	
	Help	
	Some channel labels may have kn	
	file below? If you do not know, pres	s for these channels using the electrode ss OK.
	use BESA file for 4-shell dipfit sph	erical model
	C:\Users\julie\Documents\MATLA	
	Help	Cancel Ok

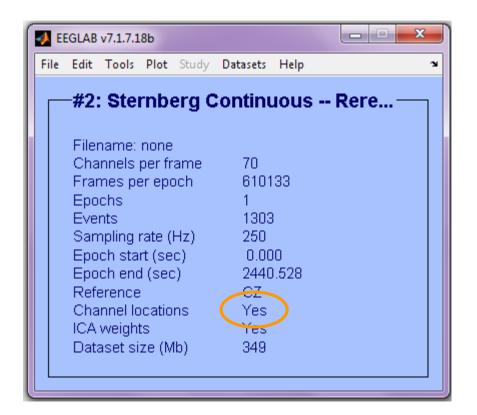
# **Import channel locations**

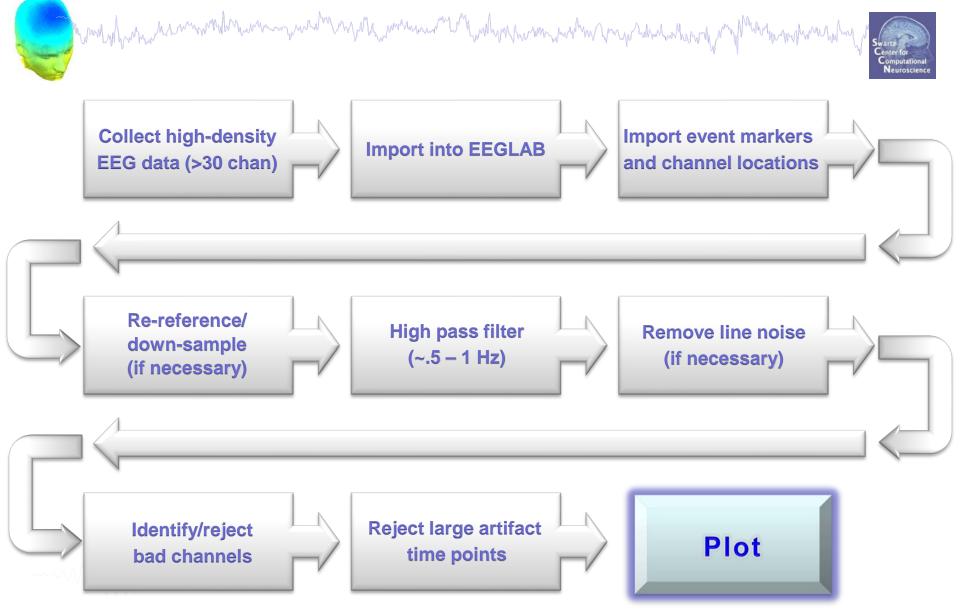




#### **Imported channel locations**



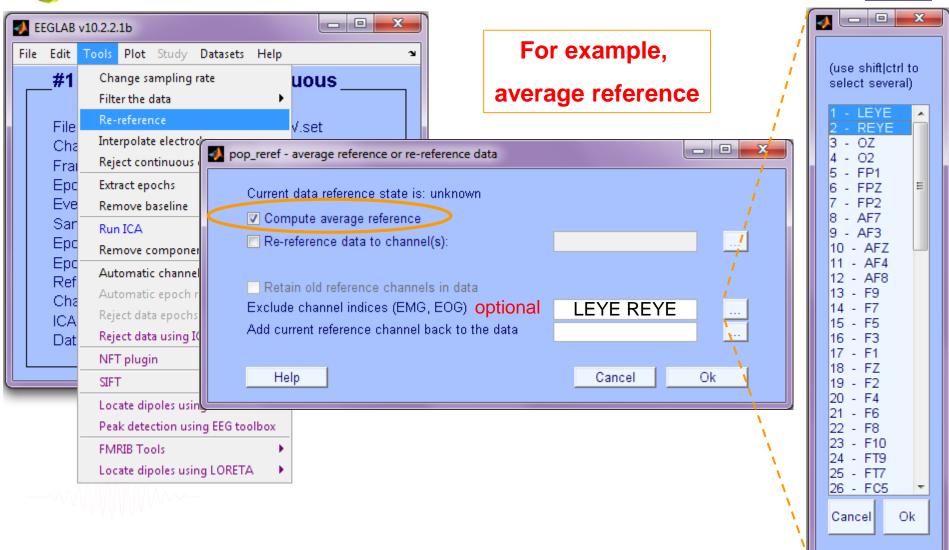




## **Re-reference data (if necessary/desired)**

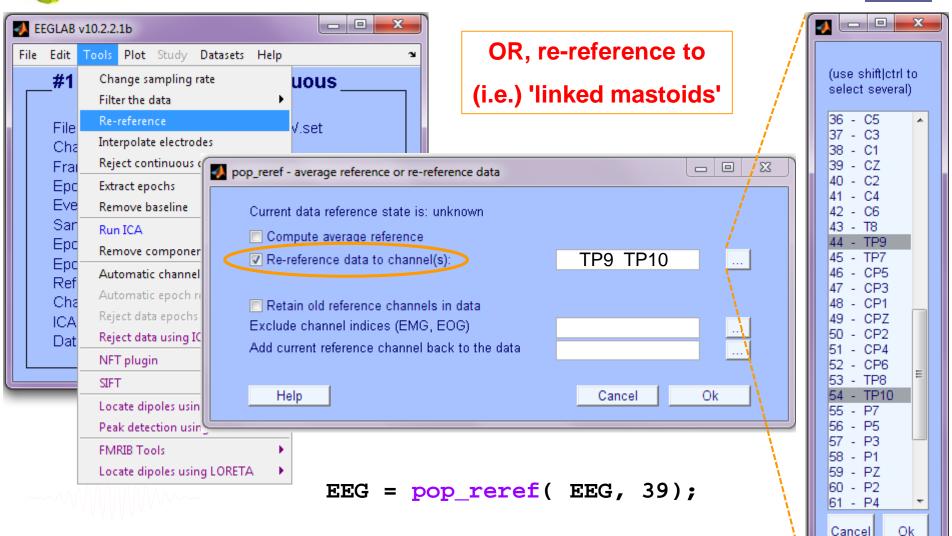
and have a property and the second of the se





#### **Re-reference data (if necessary/desired)**

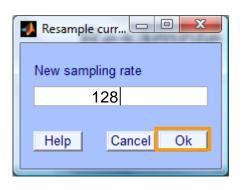




# **Resample data (if necessary)**



📣 EE	GLAB v	11.0.5.4b	
File	Edit	Tools Plot Study Datasets He	lp 🛚
	#2:	Change sampling rate	is reref
		Filter the data	•
	Filen	Re-reference	
	Char	Interpolate electrodes	
	Fram	Reject continuous data by eye	
	Epoc	Extract epochs	
	Even	Remove baseline	
	Sam Epoc	Run ICA	
	Epoc	Remove components	
	Refe	Automatic channel rejection	
	Char	Automatic epoch rejection	
	ICA v	Reject data epochs	•
	Data	Reject data using ICA	•
		Locate dipoles using DIPFIT 2.x	•

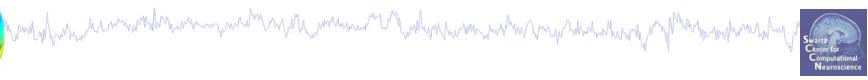


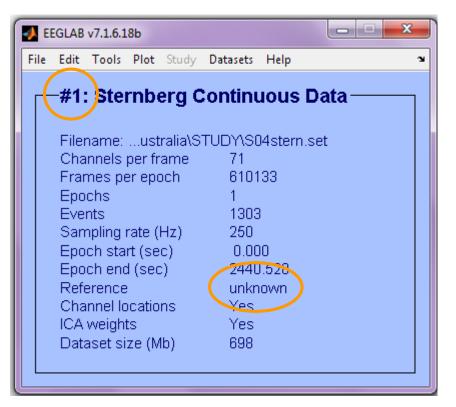
#### Save new dataset, keep old one

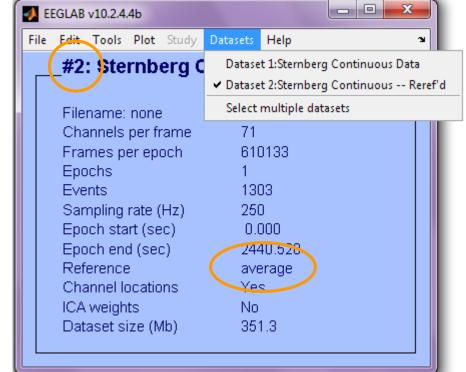
a hand have been a second	Dataset info pop_newset()	how mut when how have the second	www.www.www.www.w/www.w/ww/w/w/w/w/w/w/	Swartz Center for Computational Neuroscience
		the new dataset? Sternberg Continuous Reref'd the old dataset (not modified since la et=yes; unset=create a new dataset) Help	Edit description Browse ast saved)?	
Enter filename Save in: MATLAB Save in: MATLAB Recent Places Desktop Libraries Computer Network File name: Save as type: (*.set)	Image: Constraint of the second sec	er er er	EEGLAB v7.1.7.18b File Edit Tools Plot Study Datasets Help #2: Sternberg Continuous I Filename: none Channels per frame 70 Frames per epoch 610133 Epochs 1 Events 1303 Sampling rate (Hz) 250 Epoch start (sec) 0.000 Epoch end (sec) 2440.528 Reference CZ Channel locations Yes ICA weights Yes Dataset size (Mb) 349	Rere

~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~

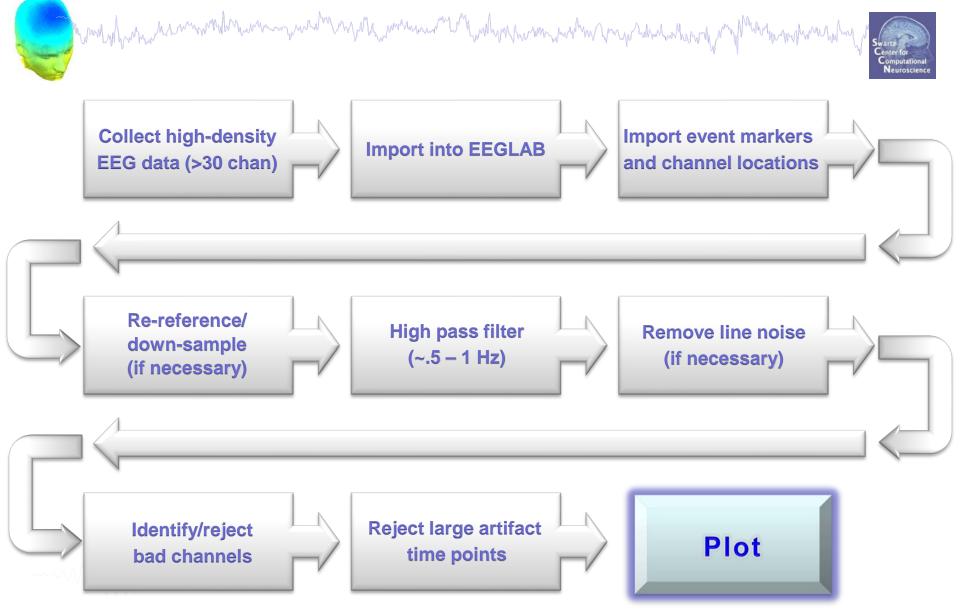
## Multiple active datasets (ALLEEG)





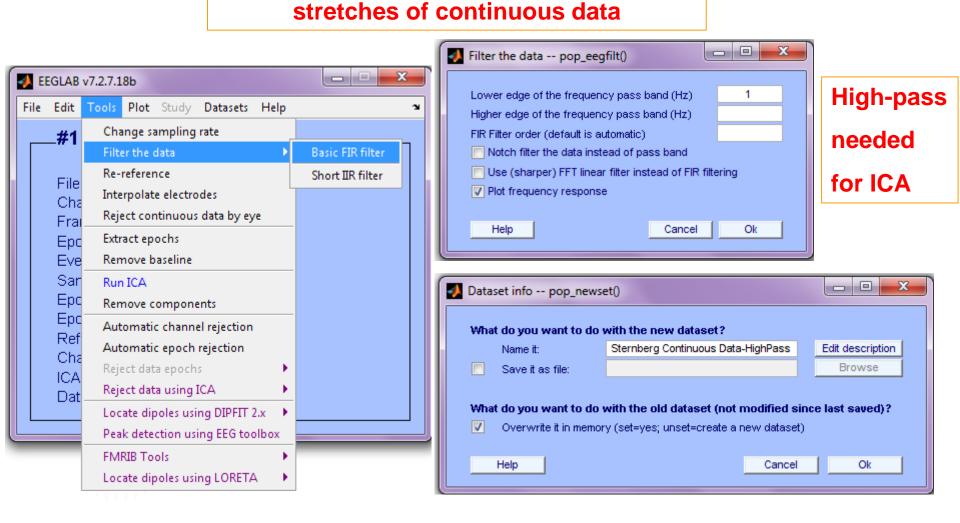


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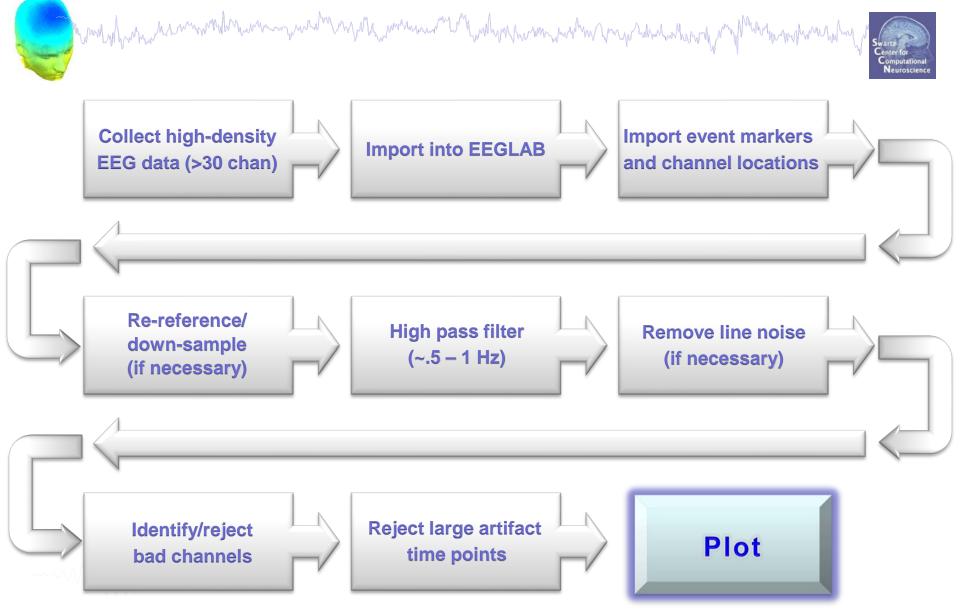


## Filter the data (if necessary/desired)

Lower cut off frequencies require longer



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ile Edit Tools Plot S	study	Datasets	Help	
Import data Import epoch info Import event info Export	> = = = = = = = = = = = = = = = = = = =	isting		
Load existing dataset Save current dataset(s) Save current dataset as Clear dataset(s)	" " bt	dataset" (data (continuous /edit		
Create study	- <b>b</b>	e dataset) data"		
Load existing study Save current study Save current study as Clear study	a in ca	ct ebochs" Remove CA"		
Memory and other options	5			
History scripts	•			
Manage plugins		Manage d	ata import plugins	
Quit		Manage data processing plugin Manage deactivated plugins		



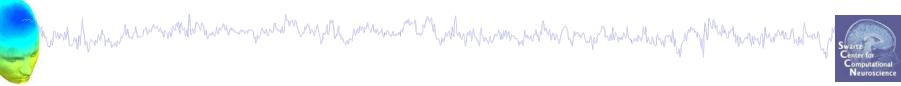
Ok

Cancel



tall		Plu	tings availab	le for install on the internet	
Install		Plugin	Version	Description	
		ERPLABfilters	1.00	Interface ERPLAB filters (requires seperate ERPLAB instalati	D
		Cleanline	1.21	Automatic artifact rejection	D
		BERGEN	1.1	Removal of fMRI-related gradient artifacts from simultaneous	D
Update	Deactivate	Plugin	Version	Installed plutings Description	
		brainmovie	0.1	Brainmovies (command line only)	D
		corrmap	2.00	New version 1.03 available. Click update to install.	D
		eeg_toolbox	1.0	Interface EEG toolbox functions for ERP peak detection	D
		fMRIb	1.21	Remove fMRI artifacts from EEG	D
		MP_clustering	1.00	Measure projection clustering of ICA components	D
		MutualInfoClustering	1.00	Mutual information clustering	D
		StudyEnvtopo	0.9	Add envtopo capabilities to STUDY	D
		VisEd	1.05	New version 1.04 available. Click update to install.	D
		iirfilt	1.02	Non linear filtering	D
		loreta	1.1	New version 1.0 available. Click update to install.	T.

# **Remove line noise (Cleanline)**



File Edit	Table Dist Churche Datasata Lisla			
	Tools Plot Study Datasets Help		CleanLine Options	
Filen Char Fram Epoc	Interpolate electrodes Reject continuous data by eye	×t	Line noise frequencies to remove Scan for line noise p-value for detection of significant sinusoid Bandwidth (Hz) Type of signal to clean	[60 120] ✓ (set) 0.01 2 Channels
Even Sam Epoc Epoc	Remove baseline Run ICA		Indices of Channels/Components to clean Sliding window length (sec) Sliding window step size (sec)	'1:66' 4 2
Refe Char ICA v Data	Automatic epoch rejection Reject data epochs		Window overlap smoothing factor FFT padding factor Visualize Original and Cleaned Spectra Normalize log spectrum by detrending	100 2 (set) (set)
	Locate dipoles using DIPFIT 2.x Peak detection using EEG toolbox FMRIB Tools Locate dipoles using LORETA CleanLine		Produce verbose output Plot Individual Figures Help	<ul> <li>✓ (set)</li> <li>Cancel</li> <li>Ok</li> </ul>

# **Plot channel spectra**

hand have been and have a second of the second



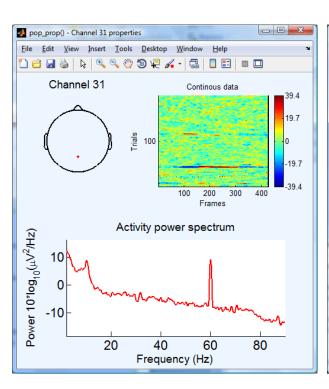
File	Edit Tools	Plot Study	Datasets Help		¥د.				
	#1: Simp	Channel	locations	•					
		Channel	data (scroll)						
	Filename:	Channel	spectra and maps		Comp	onent properties - pop_	orop()		×
	Channels pe	Channel	properties		Comp	onent properties - pop_	prop()		
	Frames per	Channel	ERP image		Cha	nnel index(ices) to plot		31	
	Epochs	Channel I	ERPs	•		ctral options (see spec			
	Events	ERP map	series	•	Ope	cital options (see spee	topo() neip).	'freqrange [2 90]	2
	Sampling ra	Sum/Cor	mpare ERPs			Uala I		Canaal	
	Epoch start - Epoch end (	Compon	ent activations (scro	1)		Help		Cancel Ok	
	Reference		ent spectra and map						
	Channel loc	Compon	ent maps	•					
	ICA weights	Compon	ent properties						
	Dataset size	Compon	ent ERP image						
		Compon	ent ERPs	+					
		Sum/Cor	mpare comp. ERPs	F					
		Data stati	stics	•					
		Time-free	quency transforms	•					
	A A A A		ataset ICs						

# **Filter comparisons**

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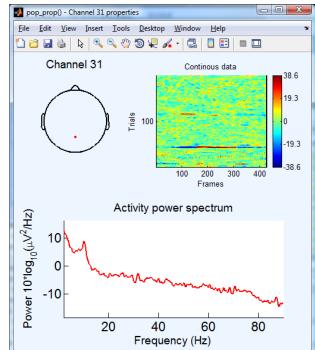
#### 0.5 Hz high-pass filter

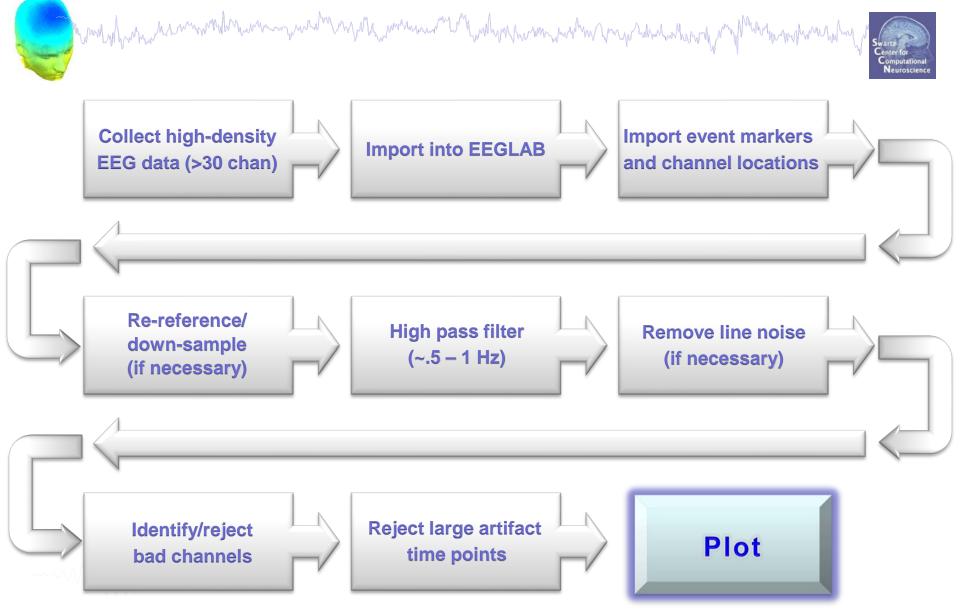


#### 0.5 Hz high-pass filter 50 Hz low-pass filter

#### - O -X pop\_prop() - Channel 31 properties Edit View Insert Tools Desktop Window Help File 🗋 🖆 🛃 🌭 🔍 🔍 🧐 🐙 🔏 - 🗔 🔲 🖽 💷 💷 Channel 31 Continous data 37.8 18.9 Trials 100 0 -18.9 -37.8 300 400 100 200 Frames Activity power spectrum Power 10\*log<sub>10</sub>(µ\<sup>2</sup>/Hz) 20 0 -20 -40 20 60 80 40 Frequency (Hz)

#### 0.5 Hz high-pass filter Cleanline: 60 Hz





# Scroll channel data

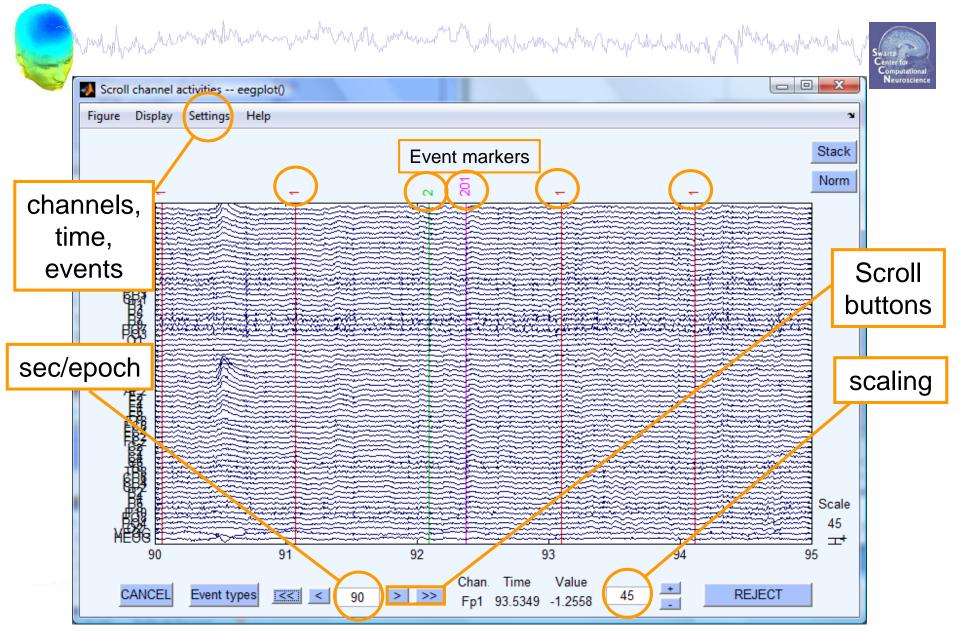


🚺 EE	GLAB v	11.0.5.4b	,			, 🗆	×	
File	Edit	Tools	Plot	Study Datasets Help				ъ
	#3:	Simp		Channel locations	×			
				Channel data (scroll)				
	Filena	ame: n		Channel spectra and maps				
	Chan	nels pe		Channel properties				
		ies per		Channel ERP image				
	Epoc			Channel ERPs	►			
	Even			ERP map series	►			
		pling ra h start		Sum/Compare ERPs				
		h end (		Component activations (scroll)				
		rence		Component spectra and maps				
	Chan	nel loc		Component maps	►			
		veights		Component properties				
	Data	set size		Component ERP image				
				Component ERPs	⊧			
				Sum/Compare comp. ERPs				
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				Time-frequency transforms	F			
				Cluster dataset ICs				
		$\Lambda \Lambda \Lambda \Lambda I$						

		11.0.5.4		-	-	-		
File	Edit	Tools	Plot	Study	Datasets	Help		2
	#1:		hange s lter the	ampling data	rate	•	hz	
	Filen Char	In		te electro	et			
	Fram Epoc	-	-		s data by eye	e		
	Even Sam		dract ep emove	base A			UI optior	٦,
	Epoc		un ICA		ame fu	unct	ion	
	Epoc	Re	emove	compon	ents		-	
	Refe	A	utomat	ic chann	el rejection			
	Char	A	utomat	ic epoch	rejection			
	ICA v	Re	eject da	ta epoch	S	►		
	Data	Re	eject da	ta using				
		Lo	ocate di	poles usi				

🚺 Warning				x			
by dragging t stretches to excise marke	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).						
	ancel	Cont	inue				

#### Scroll channel data



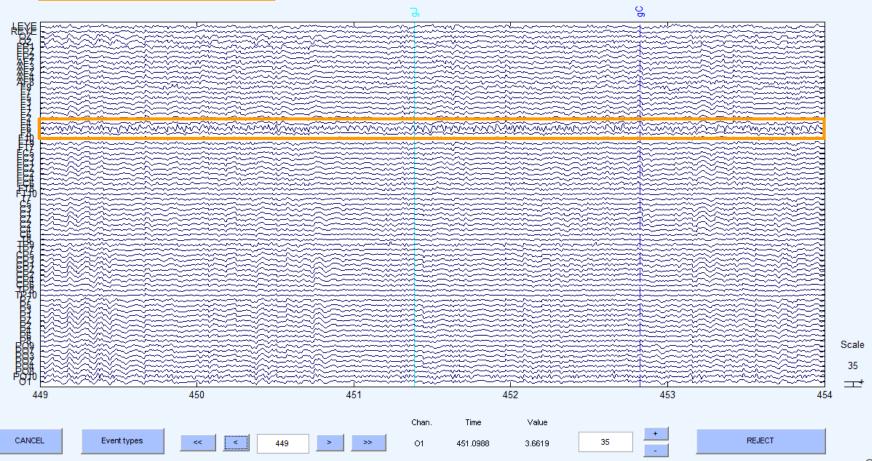
# Manually identifying bad channels

and have a second when a second when a second when a second a second

Scroll channel activities -- eegplot()

Figure Display Settings Help

#### Identify bad channel



- 0

# Manually identifying bad channels

EEGLAB v11.0.5.4b

Edit Tools

#3: Simp

Filename: n

Channels pe

Frames per

Sampling ra

Epoch start

Epoch end

Reference Channel loc

ICA weights

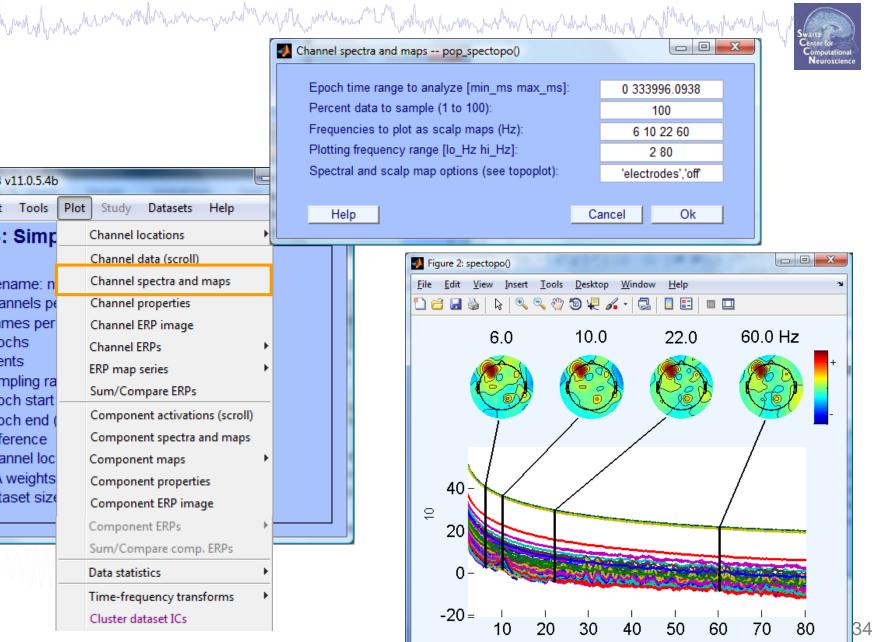
Dataset size

Epochs

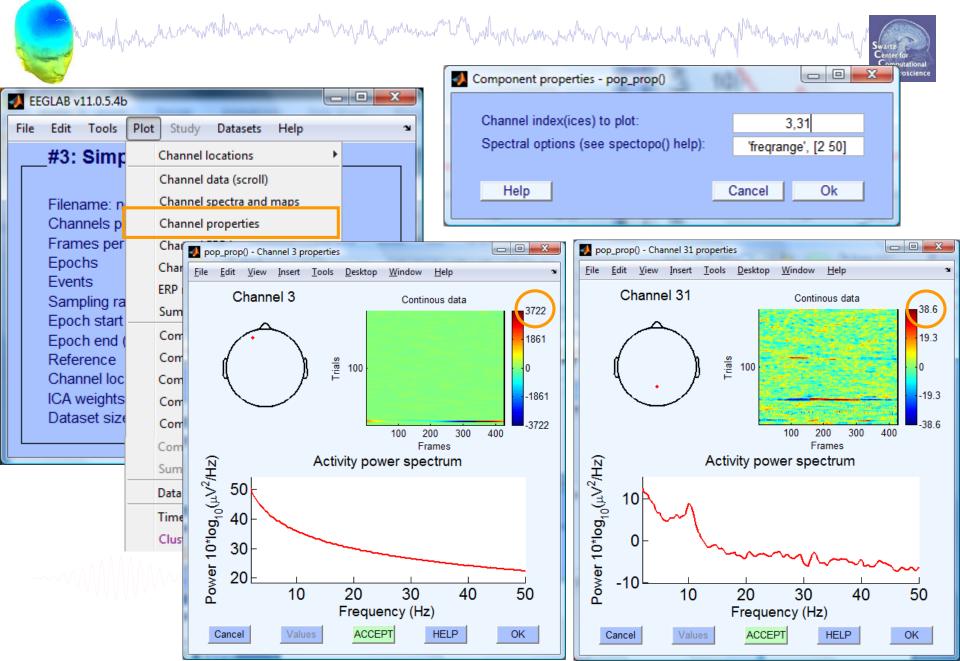
Events

Plot

File



# Manually identifying bad channels



#### **Auto-detection of noisy channels**

and have a second with a secon



	E E	GLAB	v7.1.7.1	8b				X	J
	File	Edit	Tools	Plot	Study	Datasets	Help	ע	
		-#1:		nge sa er the c	impling lata	rate	•	Data	
		Filer Cha Frar	Inte	-	e electro	des data by ey	/e	et	
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		Refe Cha	Aut	omatio		el rejectior rejection			
		ICA Data	Reje	ct dat	a using I	ICA			
L						ng DIPFIT ing EEG to			
				RIB Too ate dip		ng LORET/	► 4 ►		

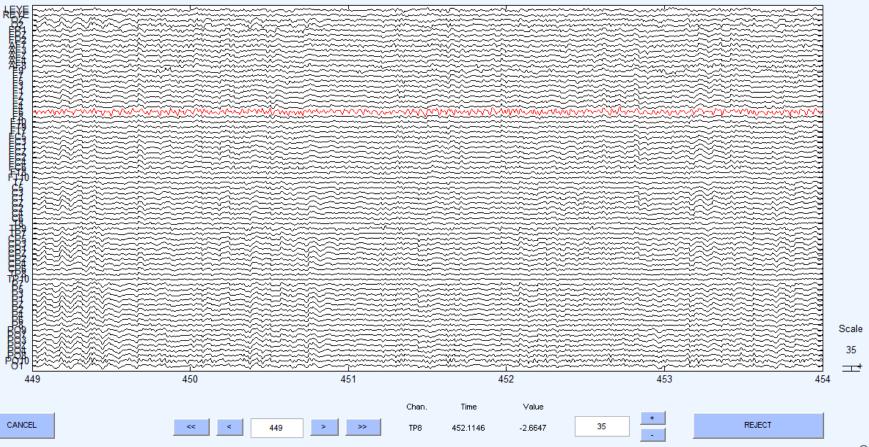
Reject channel pop_rejchan()			
Electrode (number(s); Ex: 2.4.5):	1:71		
Measure to use:	Probability 🚽		
Normalize measure (check=on):	<b>V</b>		
Threshold limits [max]:	5		
Cancel Help	Ok		

#### **Auto-detected noisy channel**



Scroll component activities -- eegplot()

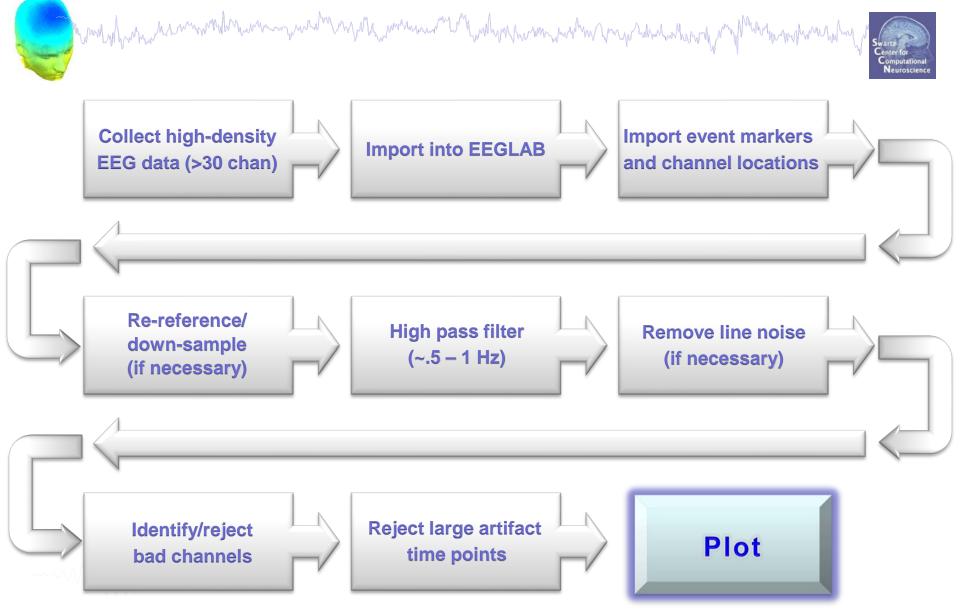
Figure Display Settings Help



## Removing channel(s)

If not checked, will result	=C2 ≡Cz Cz
	=C2 =Cz Cz
	=C2 ≡Cz Cz
26 - F	Cz
File Edit Tools Plot Study Datasets Help in dataset with one channel	
Dataset info reref 49 - C	
Event fields 50 - 0 51 - 0	
Event values 52 - T	
About this dataset 🛃 Select data pop_select()	
Channel locations 54 - C	
Select data Select data in: Input desired range on->remove these 56 - C	CP2
Select data using e Time range [min max] (s)	
Point range (ex: [1 10])         Image         58 - F           Select epochs or ev         Epoch range (ex: 3:2:10)         59 - F	
Copy current datas Chapped repres	-
Append datasets	
Delete dataset(s) Scroll dataset 63 - F	
Dataset init - pop_newset()	
What do you want to do with the new dataset?	
	lescription
Save it as file:	rowse
What do you want to do with the old dataset (not modified since last	saved)?
Overwrite it in memory (set=yes; unset=create a new dataset)	
Help Cancel	Ok

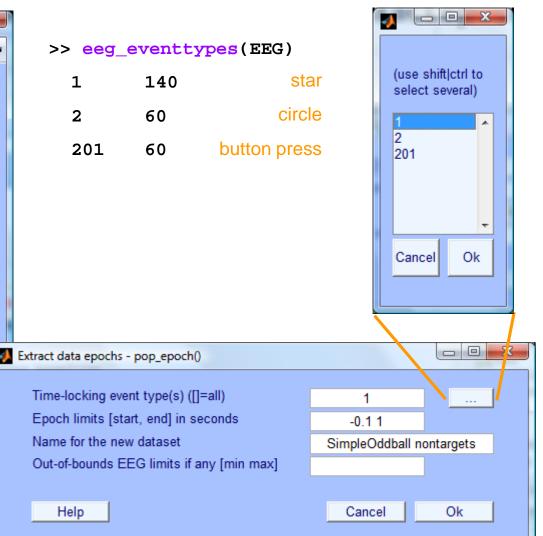
## **Pre-processing pipeline**



## **Extract epochs**

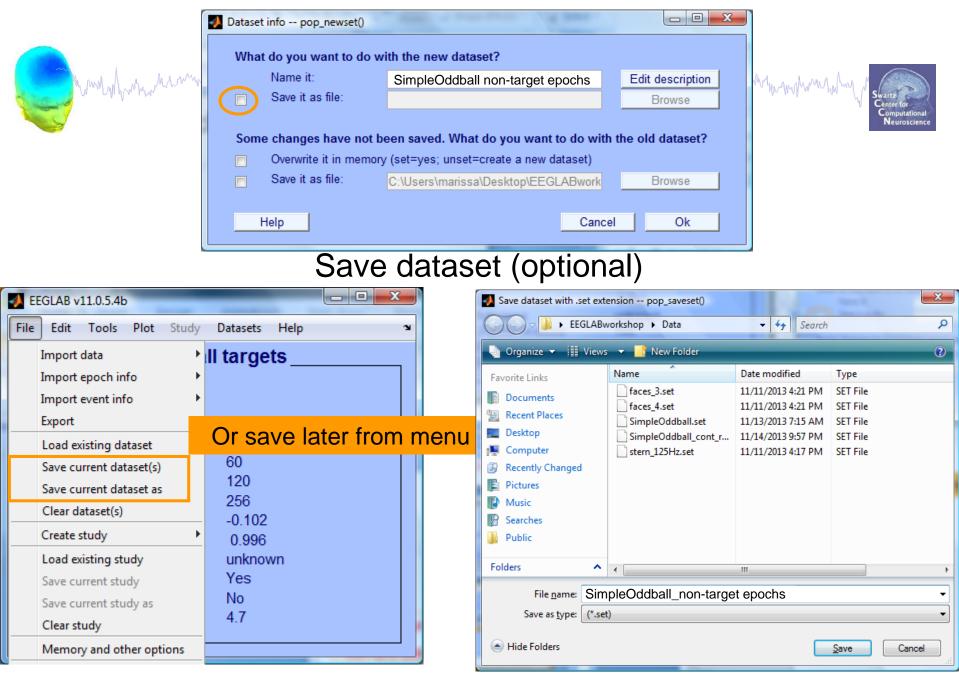


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	🧼 EE	GLAB v	11.0.5.4b	)					X	-
	File	Edit	Tools	Plot	Study	Datasets	Help			ъ
		#1: Filen Char Fram Epoc Even Sam Epoc Refe Char ICA v Data	Fil Re In Re Re Re At At At At At At At At At At At At At	ter the e-refere terpola eject co tract ep emove l un ICA emove d utomat utomat eject da eject da eject da eject da	nce te electro ntinuous bochs baseline compone ic channe ic channe ta epoch ta epoch ta using I poles usi	ents el rejection s	× ×	<u>+</u>		
				//RIB To		ng LORETA	> >			
				eanLine		IS LOKETA				
		l		λ				1		



## **Extract epochs**

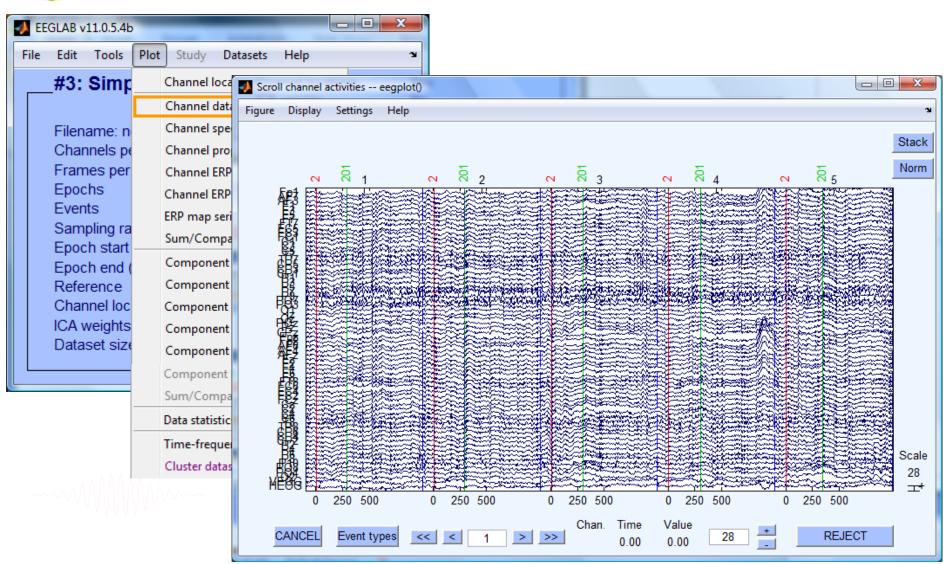
Pataset info pop_newset()	
What do you want to do w	th the new dataset?
Name it: Save it as file:	SimpleOddball nontargets Edit description
Save it as file:	Browse
Some changes have not be	een sa Epoch baseline removal pop_rmbase()
Overwrite it in memory	(set=
Save it as file:	C:\Us Baseline latency range (min_ms max_ms) ([] = ) File Edit Tools Plot Study Datasets Help
Help	-101.5625 0 #2: SimpleOddball nontargets
	(overwritten by latency range above). Filename: none
	Channels per frame 66
	Frames per epoch 282
	Help     Cancel     Epochs     140       Help     Cancel     Events     140
	Sampling rate (Hz) 256
	Epoch start (sec) -0.102
	Epoch end (sec) 0.996 Reference unknown
	Channel locations Yes
	ICA weights No
	Dataset size (Mb) 10.6



## Scroll (epoched) channel data

hand have a second with a second with a second with the second of the se



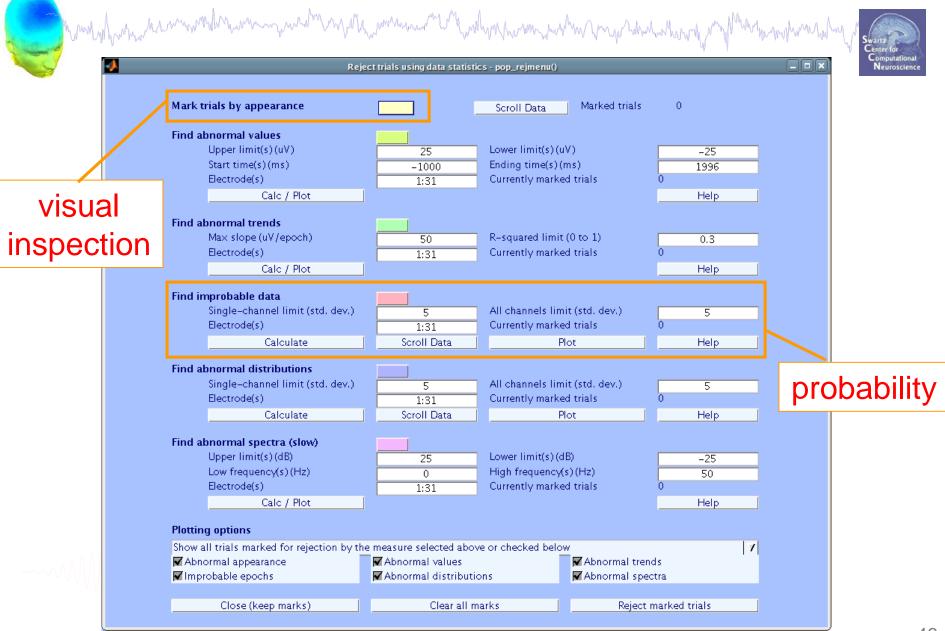


#### **Reject epochs with artifact**





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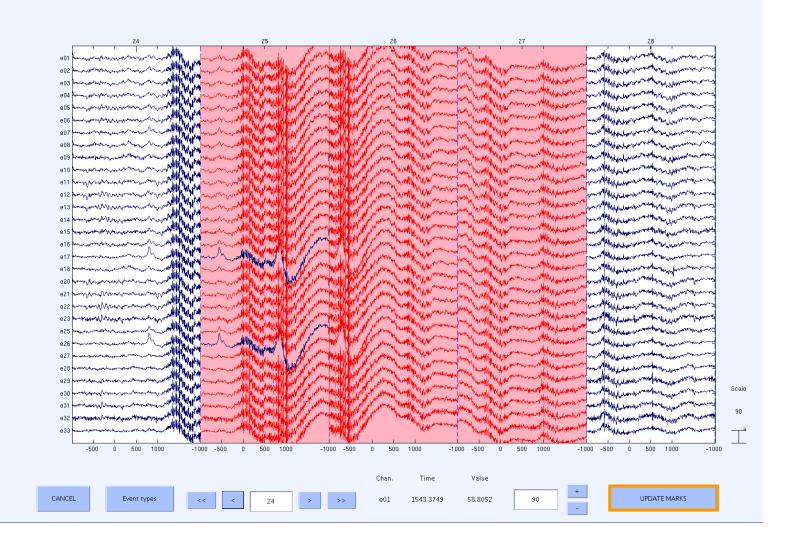


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Novice EEGLAB Workshop, Sept 22, 2011, Mallorca, Spain: Julie Onton – Evaluating ICs		No	vice EEGLAB Workshop	Sept 22, 2011	Mallorca Spain: Juli	ie Onton – Eva	luating I	Cs



Figure Display Settings Help

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Reject trials using data statistics - pop\_rejmenu(

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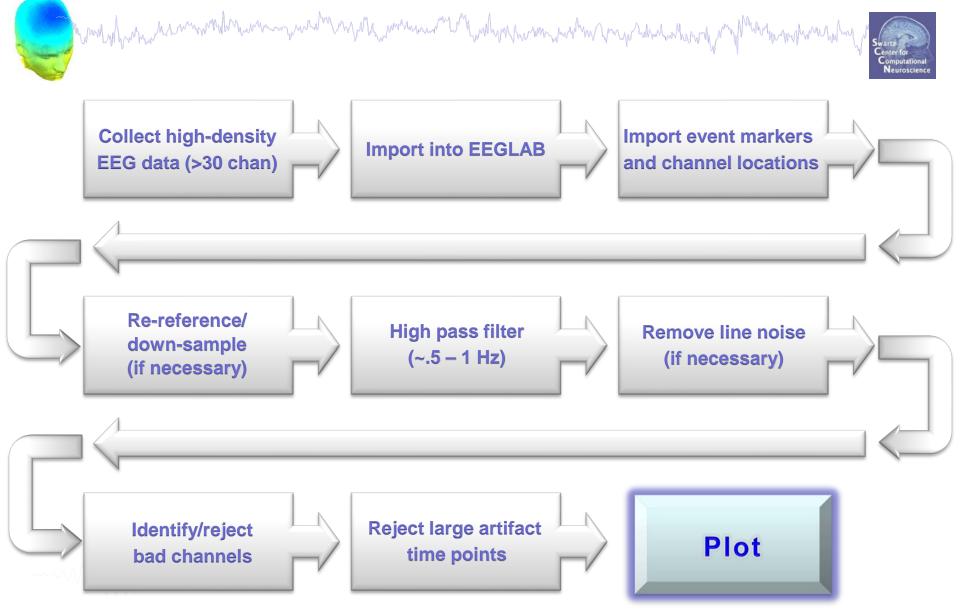
Swartz Center for Computational Neuroscience

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5	All channels limit (std. dev.)	5
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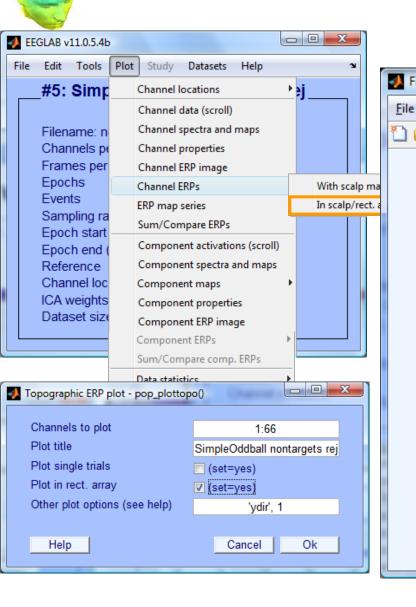
## **Pre-processing pipeline**

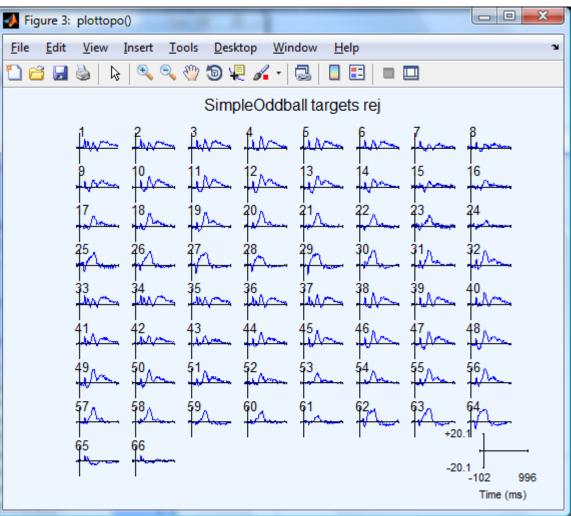


## Visualize ERP in rectangular array

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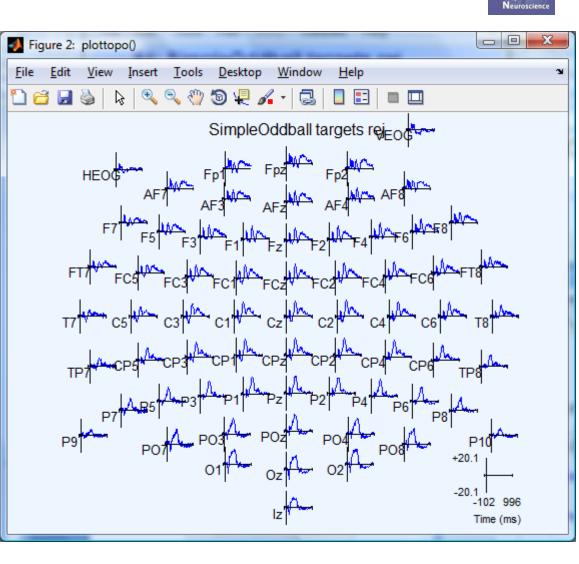




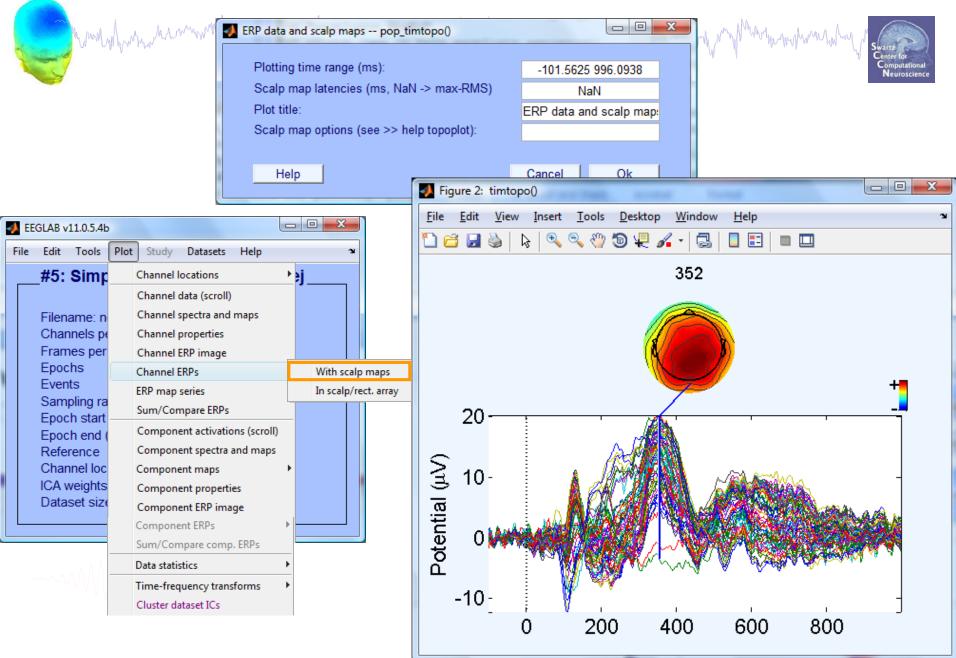


## Visualize ERP in topographic array

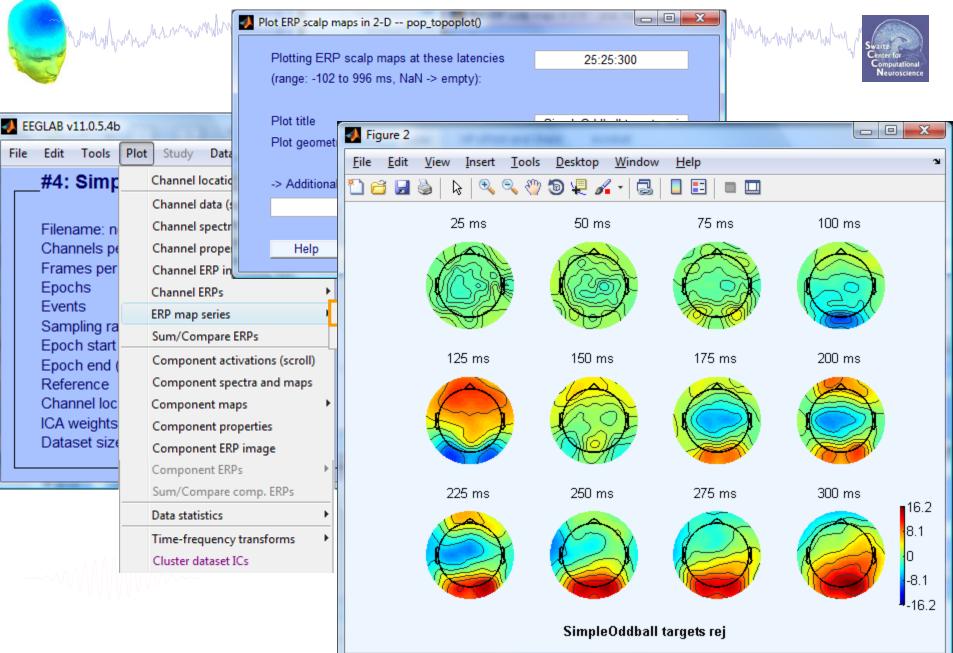
- O X EEGLAB v11.0.5.4b Plot File Edit Tools Study Datasets Help #5: Simp ⊁ ≱i Channel locations Channel data (scroll) Channel spectra and maps Filename: n Channels pe Channel properties Frames per Channel ERP image Epochs With scalp ma Channel ERPs Events ERP map series In scalp/rect. Sampling ra Sum/Compare ERPs Epoch start Component activations (scroll) Epoch end Component spectra and maps Reference Channel loc Component maps ۲ ICA weights Component properties Dataset size Component ERP image Component ERPs Sum/Compare comp. ERPs Data statistics Topographic ERP plot - pop\_plottopo() Channels to plot 1:66 Plot title SimpleOddball nontargets rej Plot single trials 📃 (set=yes) Plot in rect. array 📃 (set=yes) Other plot options (see help) 'vdir', 1 Ok Help Cancel



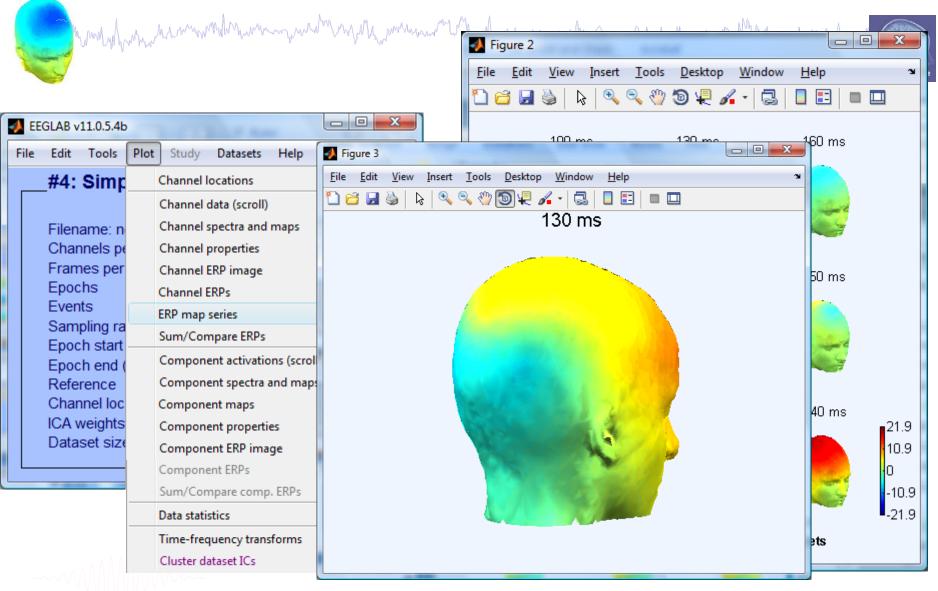
## **Visualize ERP scalp distribution**



## Visualize channel ERPs in 2D



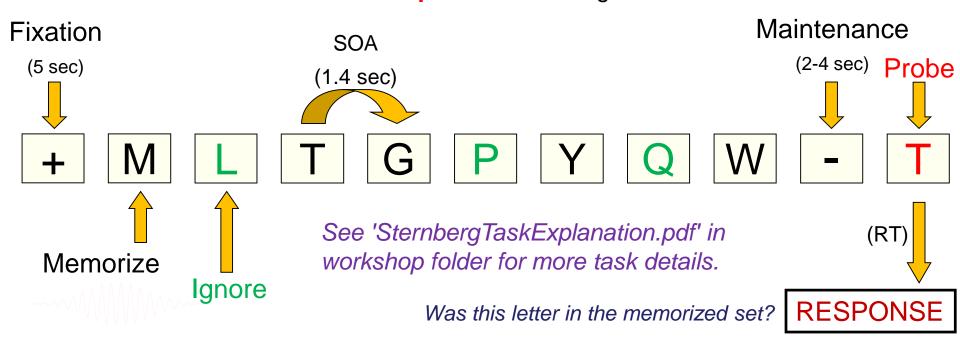
## Visualize channel ERPs in 3D



## Practice data set: Sternberg working memory

and have a server and the server and

- File .../SampleData/stern.set
- **Data** Continuous data (not epoched), ref'd to right mastoid
- Task between 3 and 7 letters to memorize (colored black), between 1 and 5 letters to ignore (colored green),
  8 letters presented during each trial
  50% chance of probe letter being 'in-set'



## Exercise

• ALL



- -Load stern\_125Hz.set (continuous data)
- -Do not save your changes under the same filename!

#### • Novice

-Scroll channel data and explore plotting options

- -Reject noisy time points and channels by visual inspection
- -Import standard channel locations

#### • Intermediate

- -Epoch the data and reject noisy epochs by auto rejection
- -Plot channel ERPs
- -Try different filter methods and cut-offs, compare results
- Advanced (requires supplementary material)
   -Compare channel ERPs across conditions

## **Supplementary lessons**





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#### **Compare ERPs across conditions**



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How do 'Memorize' and 'Ignore' ERPs differ?

#### **Compare ERPs across conditions**

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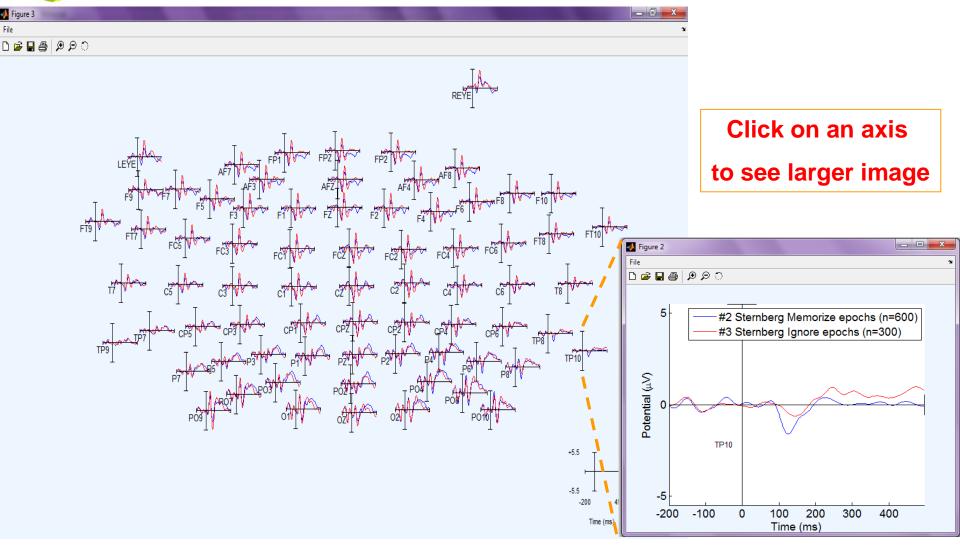
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#### **Compare ERPs across conditions**

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#### Analysis of ERP *differences*

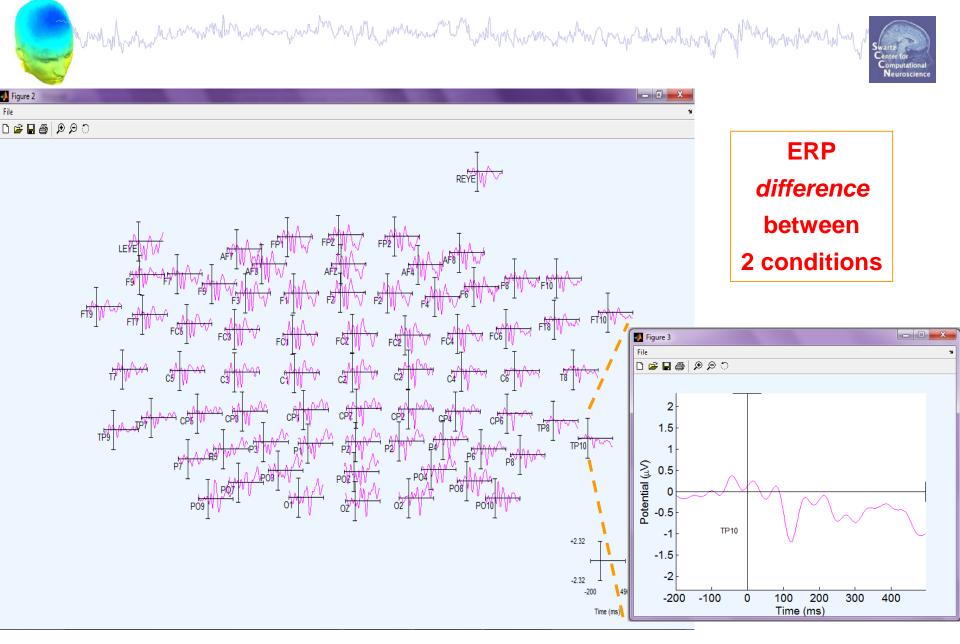




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ERP grand average/RMS - pop_compe	betwee	n two con	ditions			
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Datasets to average and subtrac	t (ex: 5 6 7):	3				
Plot difference			<b>V</b>			
Channels subset ([]=all):	[					
Highlight significant regions (.01	-> p=.01)					
Use RMS instead of average (ch	eck):					
Low pass (Hz) (for display only)		20				
Plottopo options ('key', 'val'):	Hel	p	'ydir	',1		
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```
>> pop_comperp(ALLEEG,1, 2, 3,'addavg','off',...
'addstd','off', 'diffavg','on','diffstd','off', ...
'lowpass',20, 'tplotopt',{'ydir',1});
```

#### **Analysis of ERP differences**

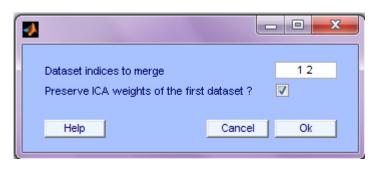


## Merge (append) datasets

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