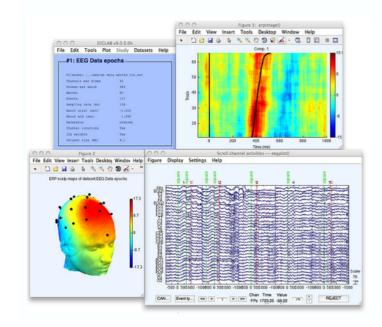
EEGLAB overview

a show when a show

- Collection of about 600 functions (70 000 lines of code)
- About 100 000 download over the past 10 years
- About 6 500 users on the discussion list and 10 500 on the diffusion list
- NIH funding since 2003

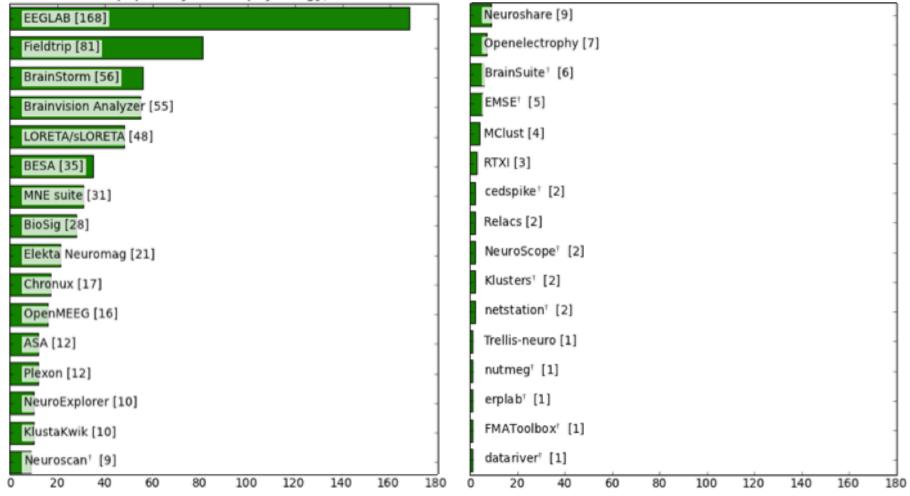
http://sccn.ucsd.edu/eeglab http://sccn.ucsd.edu/wiki/eeglab



Hanke & Helcencko, 2011, Frontier in Neuroinformatics

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Software popularity: Electrophysiology, MEG/EEG



EEGLAB standard processing pipeline

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Single subject

- 1. Import binary data, events and channel location
- 2. Edit, Re-reference, Resample, High pass filter data
- 3. Reject artifacts in continuous data by visual inspection
- 4. Extract epochs from data & reject artifactual epochs
- 5. Visualize data measures
- 6. Perform ICA decomposition
 - Perform source localization of components
 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

Multi-subjects

- 1. Build study and STUDY design
- 2. Pre-compute measures
- 3. Cluster components
- 4. Analyze clusters

Advanced analysis using scripting and EEGLAB command line functions

The EEGLAB Matlab software

hand have merely and have a second of the seco

EEGLAB Shell - Konsole _ 🗆 × Session Edit View Bookmarks Settings Help /home/arno> matlab -nodesktop EEGLAB _ = × File Edit Tools Plot Datasets Help < MATLAB> Copyright 1984-2002 The MathWork Version 6.5.0.180913a Release □ No current dataset Jun 18 2002 - Create a new or load an existing dataset: Using Toolbox Path Cache. Type "help toolbox_pa Use "/File/Import data" (new) Or "/File/Load existing dataset" (old) To get started, type one of these: helpwin, help - If new. For product information, visit www.mathworks.com "/File/Import epoch info" (data epochs), else "/File/Import event info" (continuous data) >> eeglab "/Edit/Dataset info" (add/edit dataset info) "/File/Save dataset" (save dataset) - Prune data: "/Edit/Select data" - Reject data: "/Tools/Reject continuous data" - Epoch data: "/Tools/Extract epochs" - Remove baseline: "/Tools/Remove baseline" - Run ICA: "/Tools/Run ICA"

Import/load data

:: EE	EEGLAB v4.43					
File Edit Tools Plot	Datasets Help					
Import data D	From ASCII/float file or Matlab array					
Import epoch info D	From Biosemi .BDF file					
Import event info D	From European Data Format .EDF file					
Export D	From EGL.RAW file					
Load existing dataset	From Segmented EGI .RAW files					
Save current dataset	From BCI2000 ASCII file					
Save datasets	From Snapmaster .SMA file					
Clear dataset(s)	From Neuroscan .CNT file					
Maximize memory	From Neuroscan .EEG file					
Save history D	From ERPSS .RAW or .RDF file					
Quit	From Brain Vis. Anal. Matlab file					
Dataset size (Mb)	From CTF folder (MEG)					
	From ANT .CNT file					
	From ANT .AVR file					

Import events

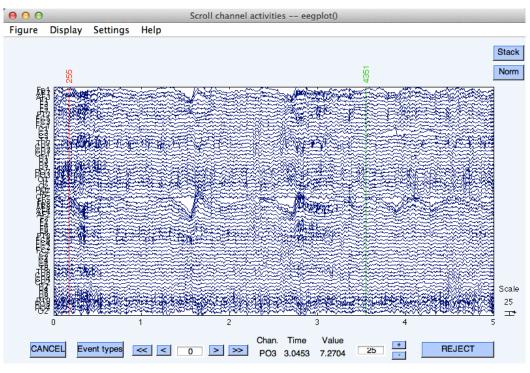
File Edit Tools Plot	Datasets Help					
Import data 🛛 🖂	epochs					
Import epoch info 🛛 🕞	epociis					
Import event info 🛛 🗠	From Matlab array or ASCII file					
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Load existing dataset	From Presentation .LOG file					
Save current dataset	75					
Save datasets	75 128					
Clear dataset(s)	-1,000					
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Quit	Yes					
ILH Weights Dataset size (Mb)	Yes 14.9					



Data info

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1	Frames	per epo	och	305	04		
	Epochs			1			
1	Events			154			
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1	Average	e refere	ence	No			
J	Channe!	l locati	ons	No			
	ICA wet	ights		No			
	Dataset	t size (МЬ)	7.9			

Scrolling data

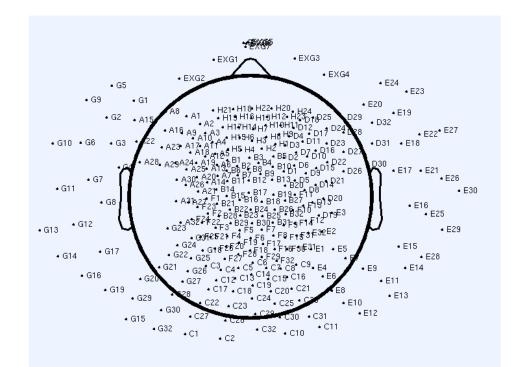


1. Importing channel location

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Import channel location

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	Event values			
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	Select data	75		
1	Select epochs/events	75		
	Copy current dataset	128		
	Append datasets	1.992		
1	Delete dataset(s)	No		
C C	hannel locations	Yes		
I	CA weights	Yes		
D	ataset size (Mb)	14.9		

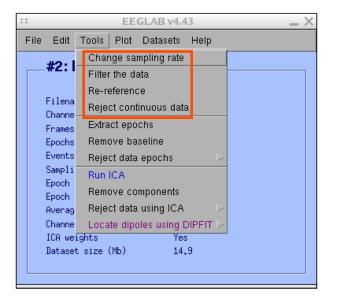


2. Edit, Re-reference, Resample, High pass filter data

Edit/select data

::							
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	Dataset info Event fields Event values About this dataset Channel locations	chs ns_ica.set 32 384					
	Select data Select epochs/events Copy current dataset Append datasets Delete dataset(s)	75 75 128 -1,000 1,392 No					
	Channel locations ICA weights Dataset size (Mb)	Yes Yes 14.9					

Preprocessing data



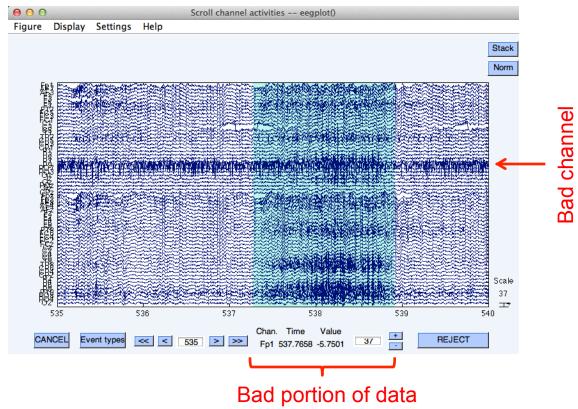
3. Reject artifacts in continuous data by visual inspection

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Data info

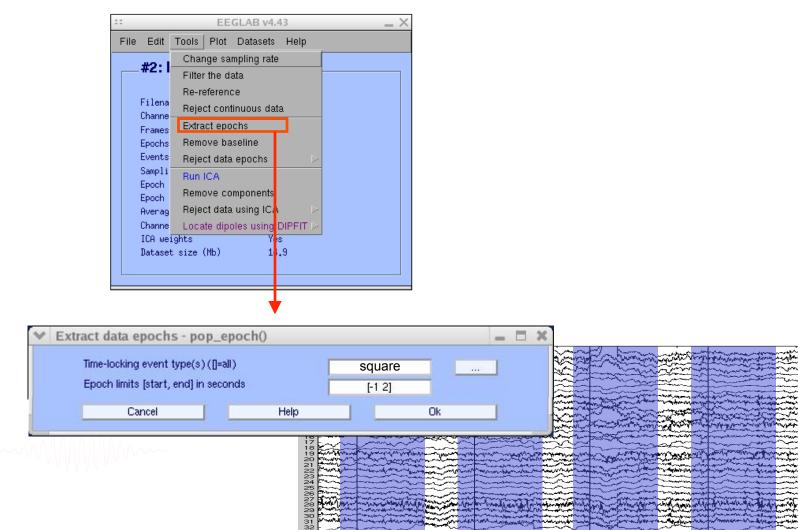
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			the di efereni					
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		size ((МЬ)		14.			

Reject portions of continuous data



4. Extract epochs from data & reject artifactual epochs

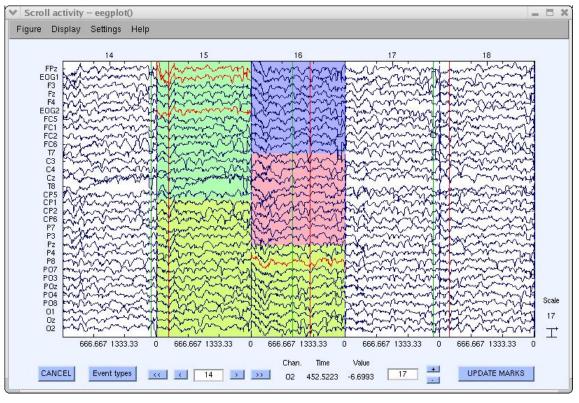
Preprocessing data



4. Extract epochs from data & reject artifactual epochs

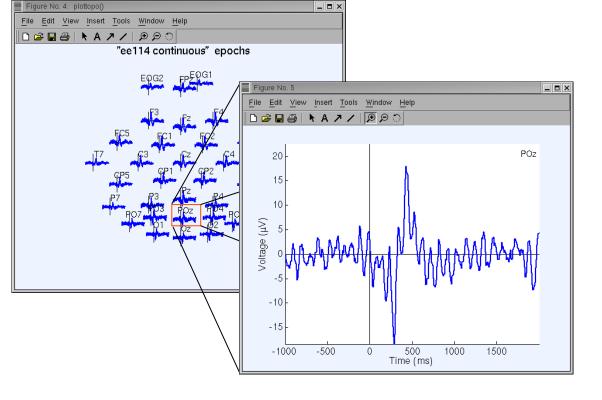
-				EE	GLAB v4.5	51		_ ×	
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		Frames Epochs		ict epo ove ba					
		Events Court i	Reje	ct data	epochs		Þ	Reject data (all method	ls)
		Sampli Epoch Epoch	Run Rem		mponents			Reject by inspection Reject extreme values	
		Averag	Reje	ct data	using ICA		Þ	Reject flat line data	
		Channe	Loca	ite dipo	oles using l	BESA	Þ	Reject by probability	
		ICA we Datase	Loca	ite dipo	oles using l	DIPFIT	⊳	Reject by kurtosis	
		240400	Lapla	acian			\geq	Reject by spectra	
			Clust	ter con	ponent		ĺ	Export marks to ICA re	ject
			Filter	r the da	ata (IIR)		Þ	Reject marked epochs	

Different color = different rejection methods



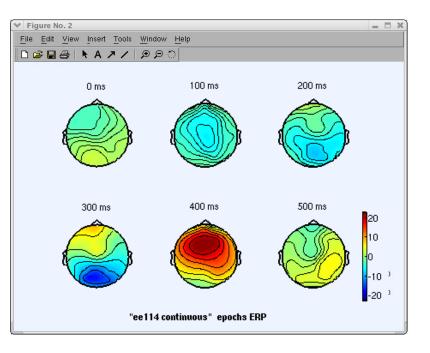
EEGLAB v4.43 $- \times$ File Edit Tools Plot Datasets Help Channel locations #1: EEG [Channel data (scroll) Channel spectra and maps Filename: eeg Channel properties Channels per H Channel ERP image Frames per epu Channel ERPs Epochs With scalp maps Events ERP map series In scalp array Sampling rate Sum/Compare ERPs In rect. arrav Epoch start (: Component activations (scroll) Epoch end (see Component spectra and maps Average refere Channel locat: Component maps ICA weights Component properties Dataset size (Component ERP image Component ERPs Sum/Compare comp. ERPs Data statistics Time-frequency transforms

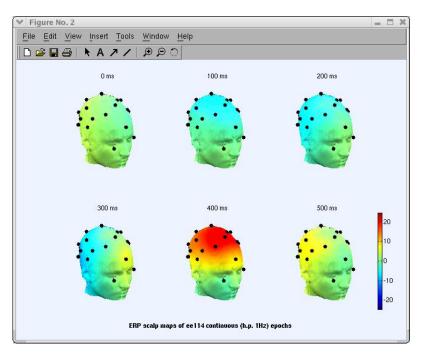
Plot ERP



Plot ERP map series

	EEGLAB v4.43	_ ×
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#1: EEG I	Channel data (scroll)	
F (1)	Channel spectra and maps	
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Average refere		
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	Sum/Compare comp. ERPs	
	Data statistics Data	
	Time-frequency transforms]

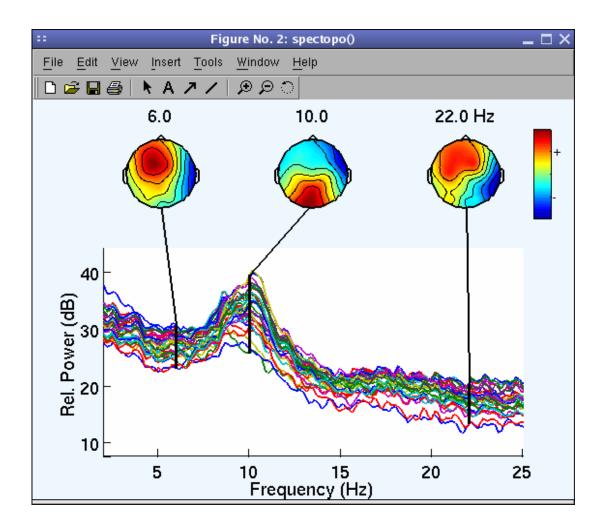




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Plot data spectrum and maps

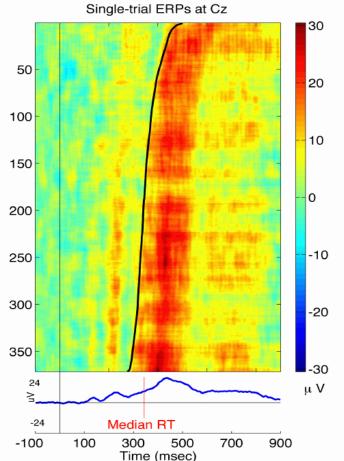
= =	EEGLAB v4.43	_ ×
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E la contra cont	Channel spectra and maps	
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	i	Data statistics		
	Ī	Time-frequency transforms		

Plot channel ERPimage



EEGLAB standard processing pipeline

way have an and the second when a second when a second of the second of

Single subject

- 1. Import binary data, events and channel location
- 2. Edit, Re-reference, Resample, High pass filter data
- 3. Reject artifacts in continuous data by visual inspection
- 4. Extract epochs from data & reject artifactual epochs
- 5. Visualize data measures
- 6. Perform ICA decomposition
 - Perform source localization of components
 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

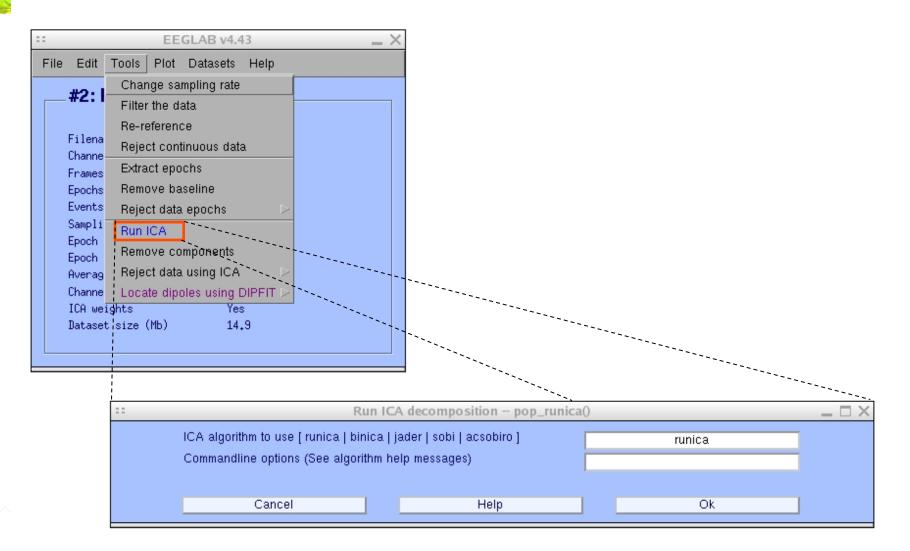
Multi-subjects

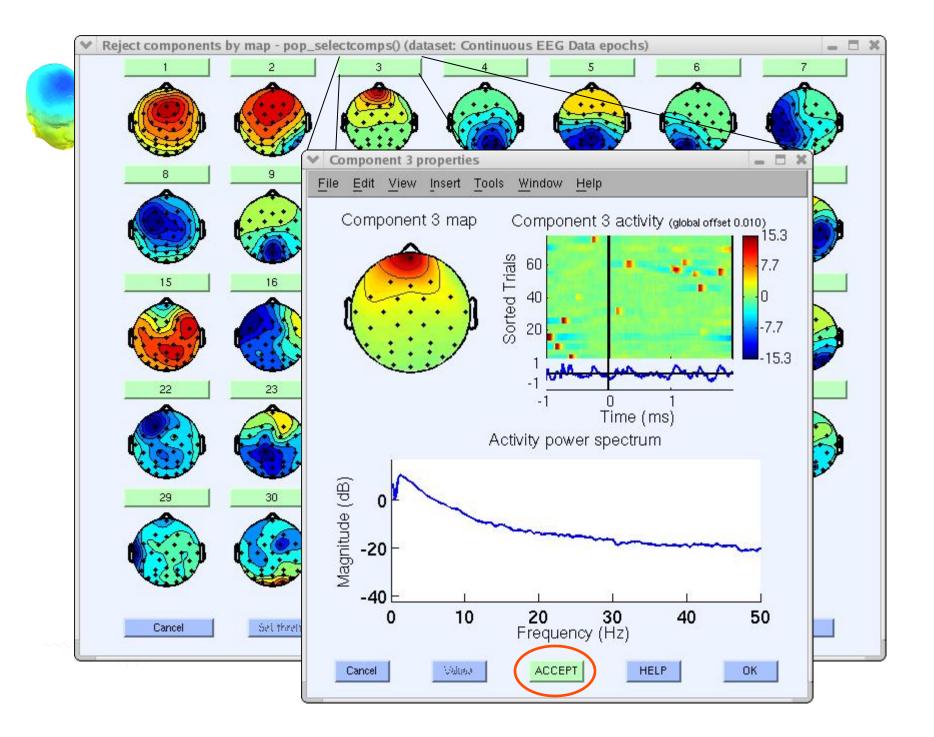
- 1. Build study
- 2. Pre-compute measures
- 3. Cluster components
- 4. Analyze clusters

Advanced analysis using scripting and EEGLAB command line functions

6. Perform ICA decomposition

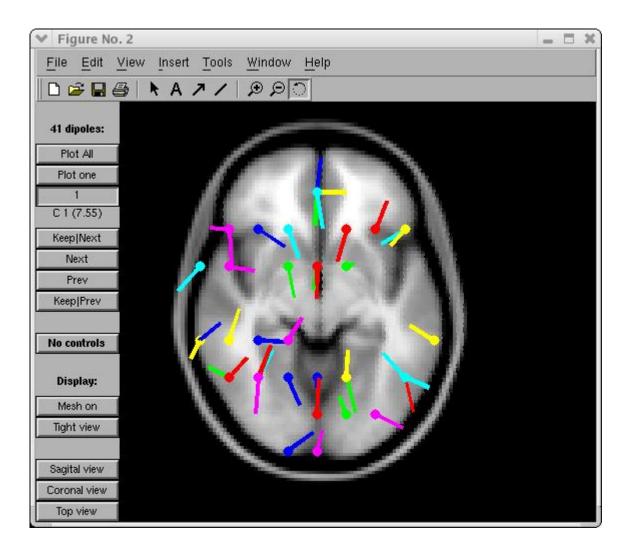
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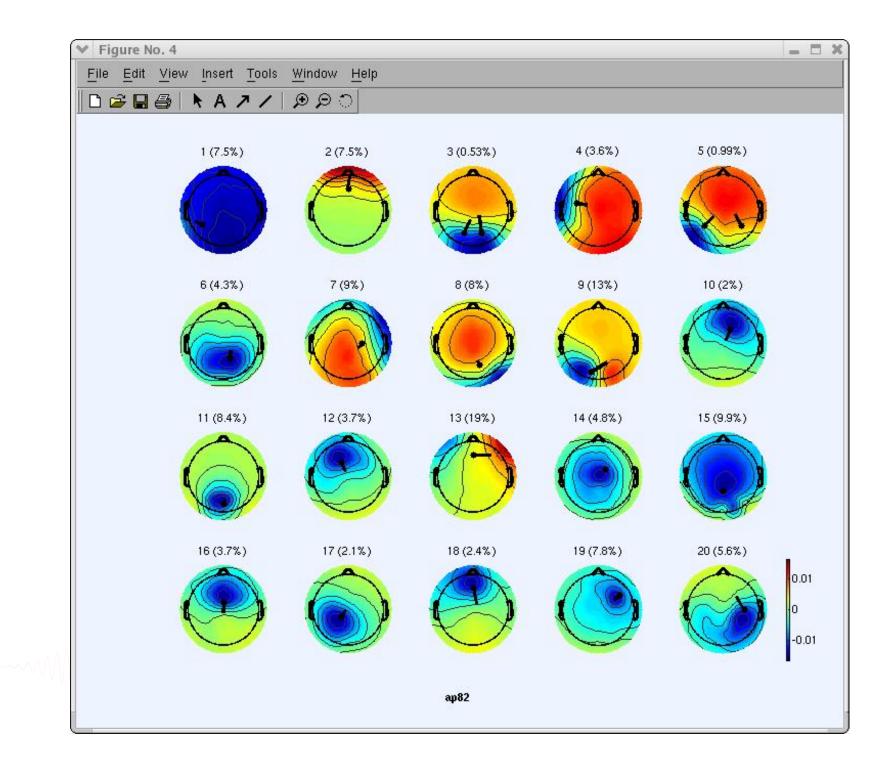




	EEGLAB v4.43	_ × _
File Edit	Tools Plot Datasets Help	
Filena Channe Frames Events Sampli Epoch Averag	Reject data epochs D Run ICA Remove components Reject data using ICA D	
Channe ICA we Datase	Locate dipoles using DIPFIT () ights Yes t size (Mb) 15.9	Autofit components Head model and settings
		Coarse fit (grid scan) Fine fit (iterative)
		Plot component dipoles

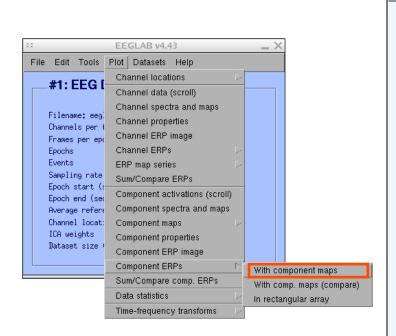


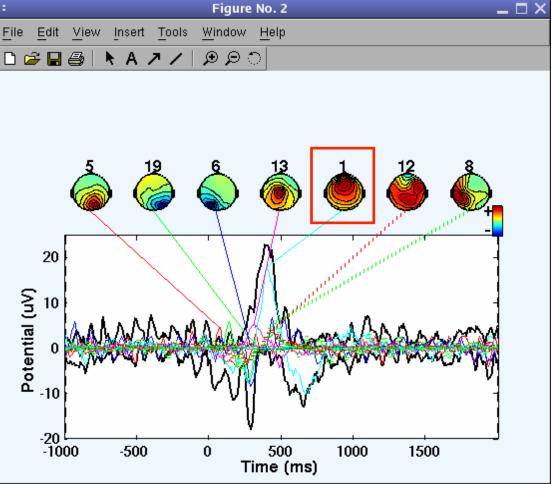




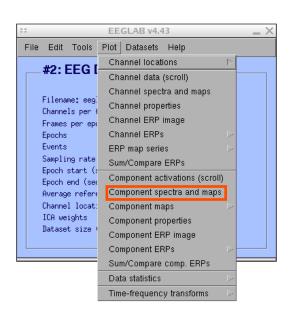
Component contribution to the ERP

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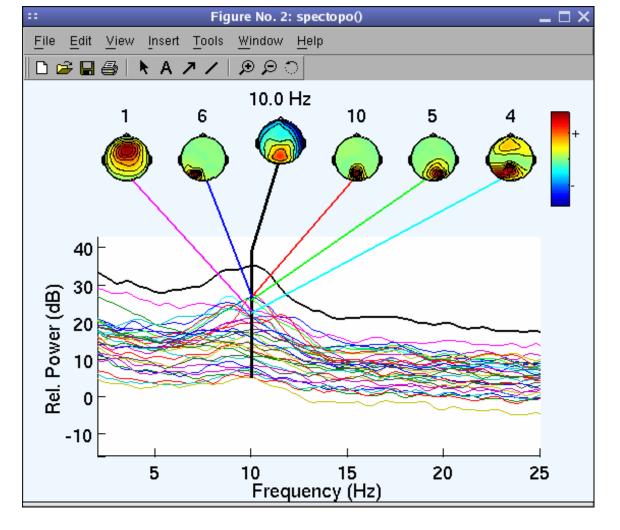




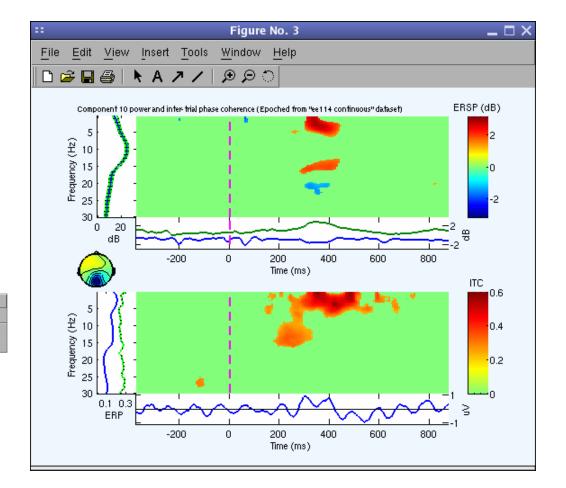
Component contribution to the EEG spectrum



humber



EEGLAB v4.43 _ X File Edit Tools Plot Datasets Help Channel locations #1: EEG I Channel data (scroll) Channel spectra and maps Filename: eeg Channel properties Channels per (Channel ERP image Frames per epo Channel ERPs Epochs Events ERP map series Sampling rate Sum/Compare ERPs Epoch start (: Component activations (scroll) Epoch end (sea Component spectra and maps Average refere Channel locat: Component maps ICA weights Component properties Dataset size Component ERP image Component ERPs Sum/Compare comp. ERPs Data statistics Time-frequency transforms Channel time-frequency Channel cross-coherence Component time-frequency Component cross-coherence



EEGLAB standard processing pipeline

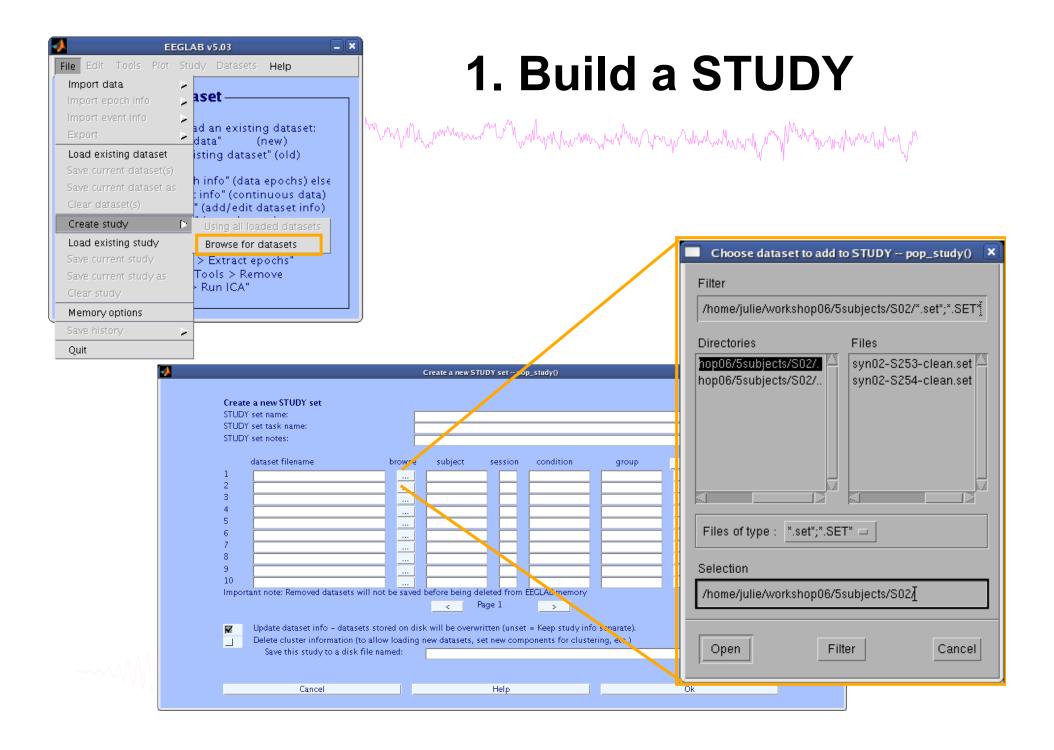
Single subject

- 1. Import binary data, events and channel location
- 2. Edit, Re-reference, Resample, High pass filter data
- 3. Reject artifacts in continuous data by visual inspection
- 4. Extract epochs from data & reject artifactual epochs
- 5. Visualize data measures
- 6. Perform ICA decomposition
 - Perform source localization of components
 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

Multi-subjects

- 1. Build study and STUDY design
- 2. Pre-compute measures
- 3. Cluster components
- 4. Analyze clusters

Advanced analysis using scripting and EEGLAB command line functions



0	0	E	EGLAB	v9.0.0.0ł)	_		
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(Channel	locations		yes				
(Clusters	1		1				
	Status			Pre-cl	ustered			
	Total si	ze (Mb)		8.2				

idit STUDY design

Select STUDY design		
STUDY.design 1		Add design
		Rename design
		Delete design
Subjects	Independent variable 1	Independent variable
S05 S08	None condition description	None condition description
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	Combine selected values)	Combine selected val
Select all subjects	Unpaired statistics \$	Unpaired statistics
Use only specific datas	ets/trials	
	sociated with this STUDY design	



2. Pre-compute measures

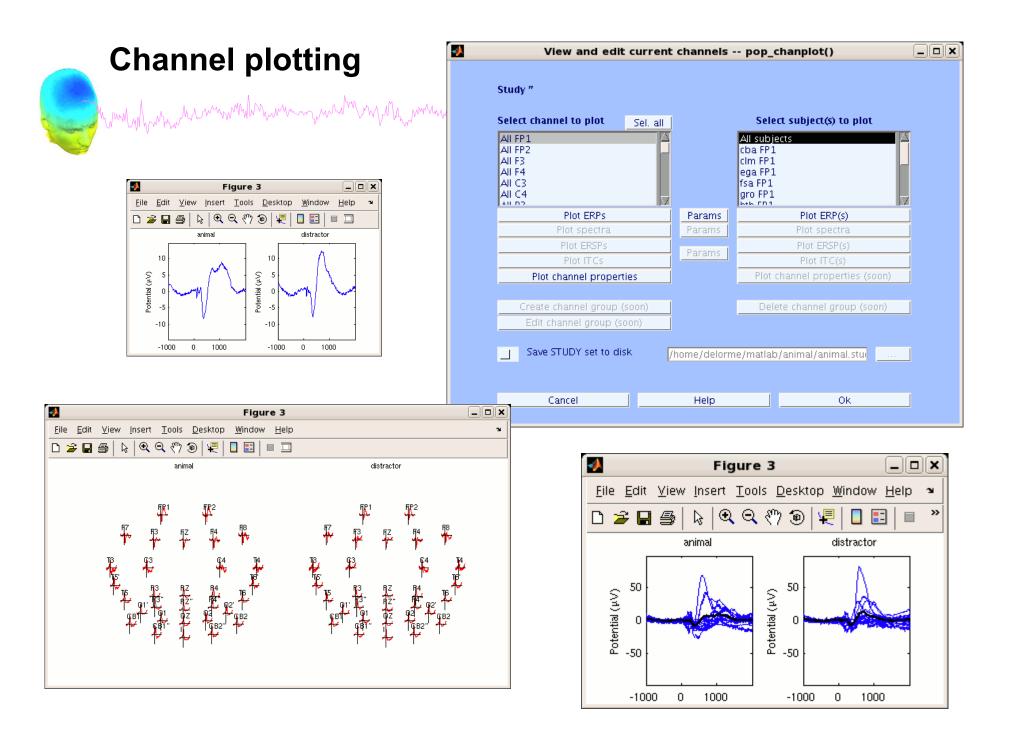
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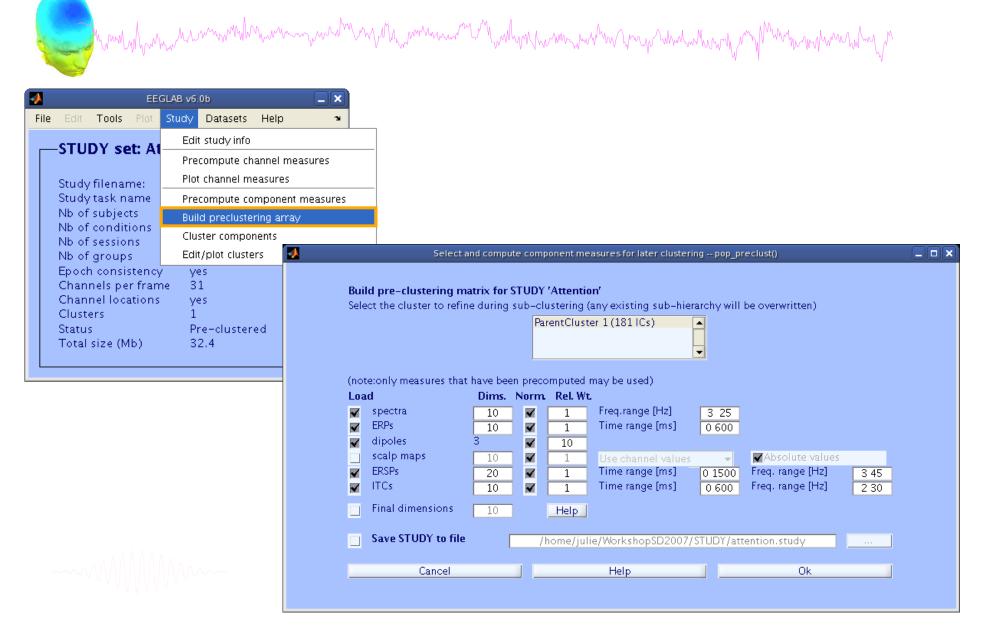
File Edit Tools Plot	Study Datasets Help
STUDY set:	Edit study info Select/Edit study design(s)
Study filename:s/data	Precompute channel measures
Study task name	Plot channel measures
Nb of subjects Nb of conditions Nb of sessions Nb of groups Epoch consistency	Precompute component measures Measure Product clustering PCA clustering (original) Edit/plot clusters
Channels per frame	61
Channel locations	ves
Clusters	1
Status	Pre-clustered
Total size (Mb)	8.2

	Datasets Help	Study	Plot	Tools	Edit	File
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ng 🕨	ure Product clusteri			ssions	Nb of se	1
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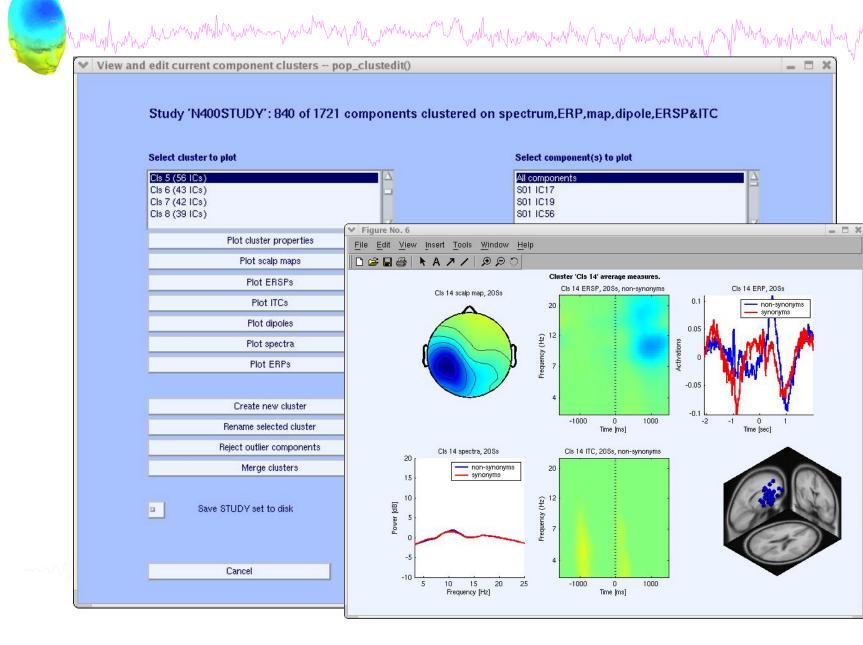
OOO Select and cor	npute component measures for later clustering pop_precomp()						
Pre-compute channel measures for STUDY " - 'STUDY.design 1'							
Channel list (default:all)							
Spherical interpolation	on of missing channels (performed after optional ICA removal below)						
Remove ICA artifactual components pre-tagged in each dataset							
Remove artifactual I	ParentCluster 1 CA cluster or clusters (hold shift key)						
List of measures to pred	compute						
ERPs	Baseline ([min max] in ms)						
Power spectrum	Spectopo parameters 'specmode', 'fft' Test						
ERSPs	Time/freq. parameters 'cycles', [3 0.5], 'nfreqs', 100 (Test)						
Save single-trial measures for single-trial statistics - requires disk space Recompute even if present on disk							
Help	Cancel Ok						

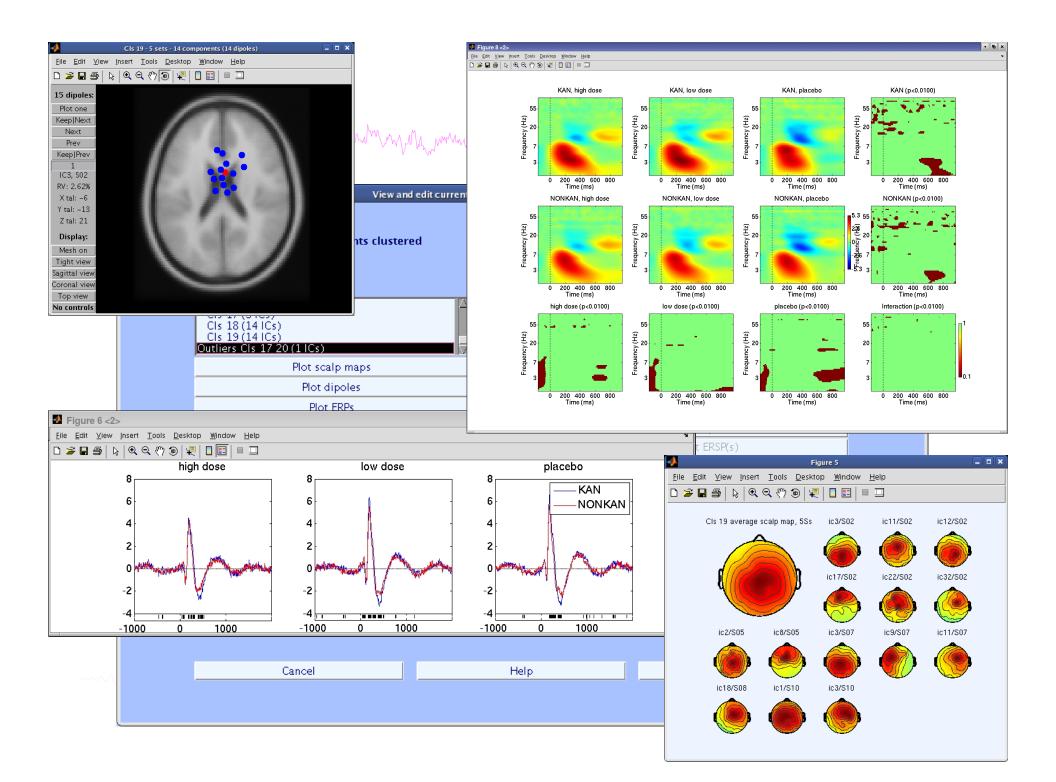


3. Cluster components



4. Analyze clusters





EEGLAB standard processing pipeline

Single subject

- 1. Import binary data, events and channel location
- 2. Edit, Re-reference, Resample, High pass filter data
- 3. Reject artifacts in continuous data by visual inspection
- 4. Extract epochs from data & reject artifactual epochs
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 - Perform source localization of components
 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

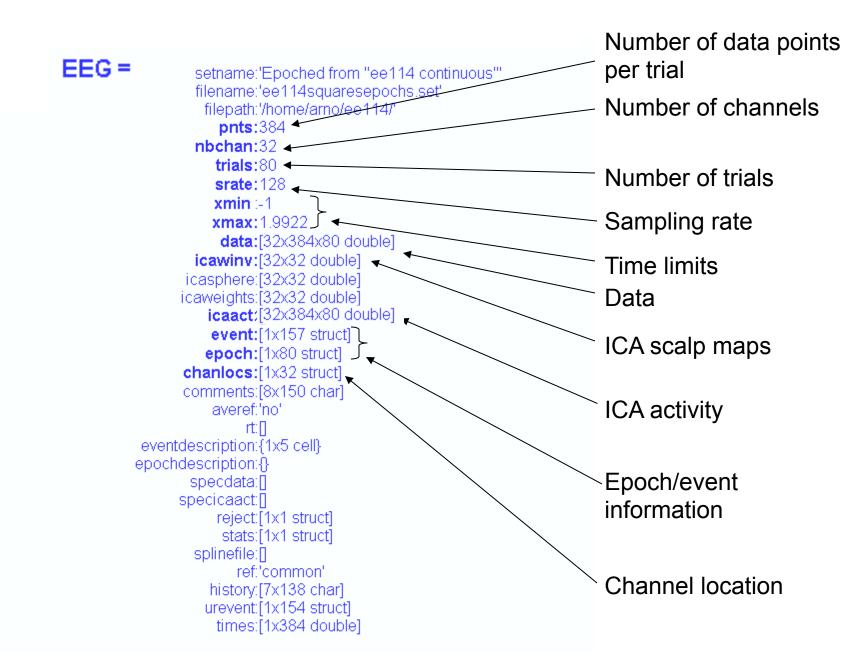
Multi-subjects

- 1. Build study and design
- 2. Pre-compute measures
- 3. Cluster components
- 4. Analyze clusters

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#### Advanced analysis using scripting and EEGLAB command line functions

# **EEG** structure



# 3 levels of functions

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Administrative functions: handle EEG and ALLEEG structures eeglab(), eeg\_checkset(), pop\_delset(), ...

Pop functions: interactive functions using EEG structure pop\_erpimage(), pop\_topoplot(), pop\_envtopo(), ...

Signal processing functions: perform signal processing erpimage(), topoplot(), envtopo(), ...



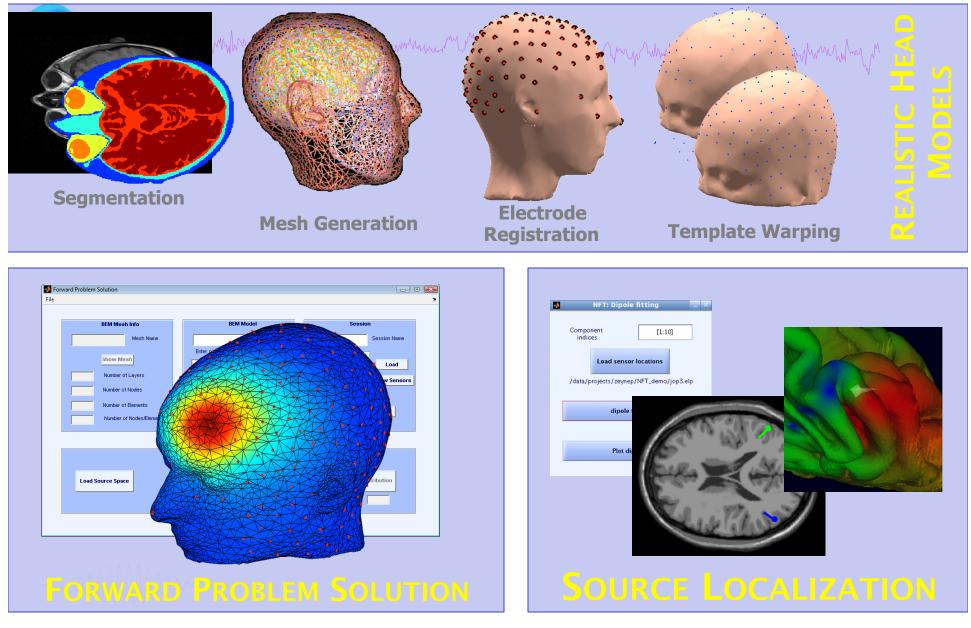
# Command line tools

("eegh" Menus write both dataset and global history)

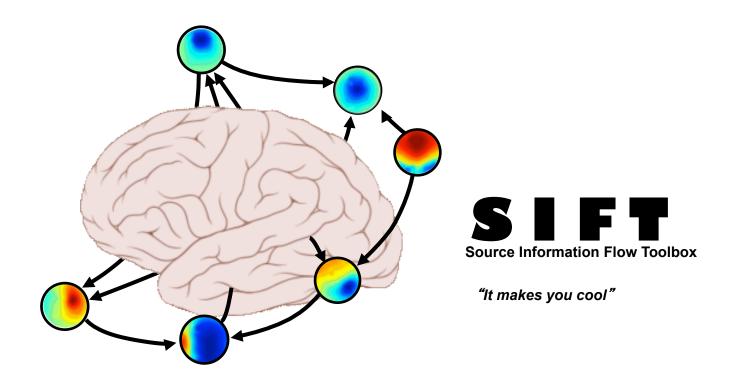
- Automated processing on groups of subjects (possibly on several processors).
- Richer options for plotting and processing functions (time-frequency decompositions, ...)
- Custom processing...

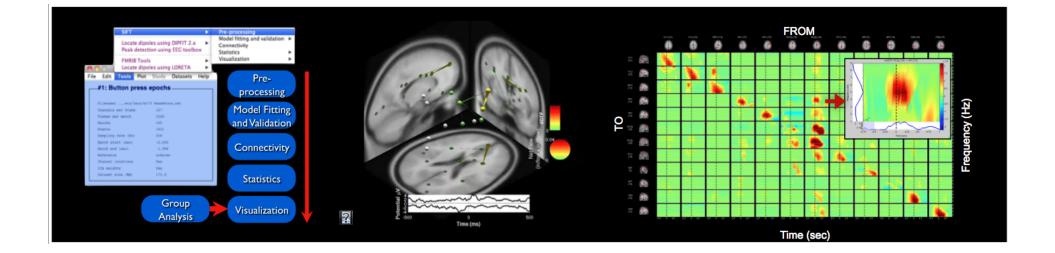


### NFT: Neuroelectromagnetic Forward Head Modeling Toolbox

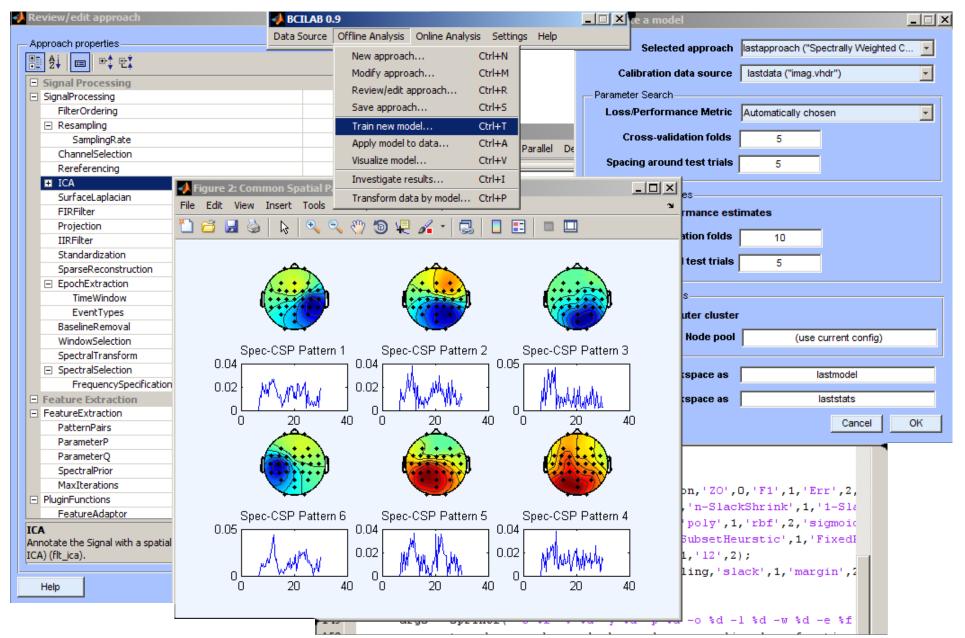


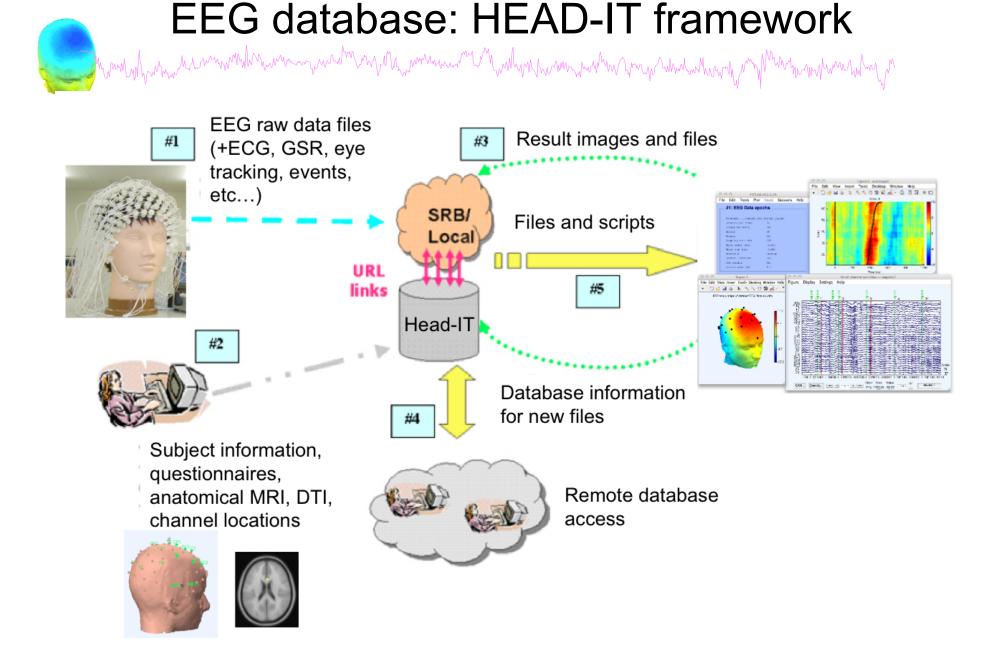
http://sccn.ucsd.edu/nft





# BCILAB - C. Kothe





# Pros/Cons of Matlab based open source

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- Pros
  - Easy to program, highly modular and extendable
  - Not dependent on any platform (64-bit)
  - Large community of users (latest development in signal processing research)
  - Cannot imagine more powerful scripting capabilities
- Cons
  - Matlab required for which you have to pay
  - Large memory requirements
  - Matlab bugs, possible version differences, cross platform compatibility problems

#### Tuesday, June 18th

7:00 - 8:30 Breakfast

#### **Overview and ICA Theory/Practice**

8:30 - 9:30 -- Mining event-related brain dynamics I (Scott Makeig)
9:30 - 10:00 -- EEGLAB overview (Arnaud Delorme)

Break-

10:15 - 11:15 -- ICA theory (Tim Mullen)

11:15 - 12:00 -- Data import, Artifact rejection and running ICA (Claire Braboszcz)

12:00-13:00 Lunch --

#### ICA and time-frequency

13:00 - 14:00 -- Importing data, rejecting data, and performing ICA decomposition practicum (Claire Braboszcz)
14:00 - 15:00 -- Evaluating ICA components practicum (Arnaud Delorme)

Break-

15:30 - 17:00 -- Time-frequency decompositions: Theory and practice (Tim Mullen)

17:00 - 19:00 -- Data and processing assistance available

19:00 -- Dinner

#### Wednesday, June 19st

7:30 - 8:30 Breakfast

#### **Overview and ICA Theory/Practice**

8:30 – 9:00 -- Why cluster ICA components? (Scott Makeig)
9:00 – 10:00 -- Group analysis using EEGLAB studies: Methods to cluster ICA components (Arnaud Delorme)

-- Break--

10:15 - 11:15 -- Group analysis using EEGLAB studies: Methods to plot data and compute statistics (Arnaud Delorme)

11:15 – 12:00 -- Scripting to manipulate EEGLAB studies for group analysis (Arnaud Delorme)

#### 12:00-13:00 Lunch --

#### ICA, time-frequency and information flow

13:00 – 14:00 -- Robust statistics: central tendency, dispersion and inference (Guillaume Rousselet)
14:00 – 14:30 -- Statistical estimation in EEGLAB (Arnaud Delorme)

14:45-18:00-- Excursion to Saint-Bertrand-de-Comminges (http://en.wikipedia.org/wiki/Saint-Bertrand-de-Comminges)



#### Thursday, June 20th

#### 7:30 - 8:30 Breakfast

#### Source Localization

8:30 – 9:30 -- Forward and inverse models - the Dipfit plugin (Robert Oostenveld)
9:30 – 10:00 -- The Neuroelectromagnetic Forward Head Modeling (NFT) EEGLAB plugin (Scott Makeig)

-- Break--

#### General Linear Modeling

10:15 – 12:00 -- Theory and practice of applying general linear models to EEG data using the LIMO EEGLAB plug-in (Cyril Pernet)

#### 12:00-13:00 Lunch --

#### Source information flow

13:00 - 14:00 -- Source information flow and Granger-Causal modeling tools (Tim Mullen)

14:00 – 15:00 -- SIFT toolbox: Theory and live demo (Tim Mullen)

-- Break--

15:30 - 17:00 -- SIFT toolbox: practicum (Tim Mullen)

17:00 - 19:00 -- Data and processing assistance available

#### 19:00 -- Dinner

22:00 - 24:00 -- SIFT hackathon, meet with Tim Mullen and his computer at the bar - ask anything you like

22:00 - 24:00 -- LIMO hackathon, meet with Cyril Pernet and his computer at the bar - ask anything you like

#### Friday, June 21st

#### 7:30-8:30 -- Breakfast

8:30 – 9:30 -- Mining event-related brain dynamics II (Scott Makeig) 9:30 – 10:00 -- Using and building EEGLAB plug-ins (Arnaud Delorme)

#### -- Break--

10:15 – 11:30 -- Practicum, small group projects 11:30 – 12:00 -- Participant project presentations and general discussion



12:00 -- Lunch

# **EEGLAB** articles

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Delorme, A., Makeig, S. (2004) EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, 134(1), 9-21.

Makeig, S., Debener, S., Onton, J., Delorme, A. (2004) Mining event related dynamics. *Trends in cognitive Neuroscience*, 8(5), 204-210.

Delorme, A., Kothe, C., Bigdely, N., Vankov, A., Oostenveld, R., Makeig, S. Matlab Tools for BCI Research? In "human-computer interaction and braincomputer interfaces". Editors : Tan, D. and Nijholt, A. To appear in 2010. Springer Publishing.

Delorme, A., Mullen, T., Kothe, C., Bigdely-Shamlo, N., Akalin, Z., Vankov, A., Makeig, S. EEGLAB, MPT, NetSIFT, NFT, BCILAB, and ERICA: New tools for advanced EEG/MEG processing. Computational Intelligence, accepted.

Delorme, A., Makeig, S. Open Source Programming for Interpreted Language: Graphic Interface and Macro Bridging Interface. IEEE International Conference on Signal Image Technology and Internet Based Systems. In press.