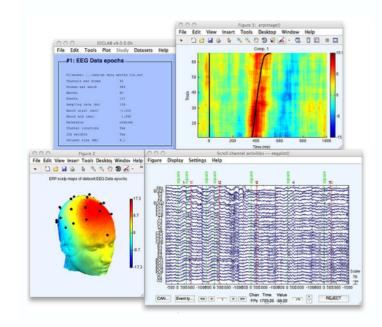
EEGLAB overview

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



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	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

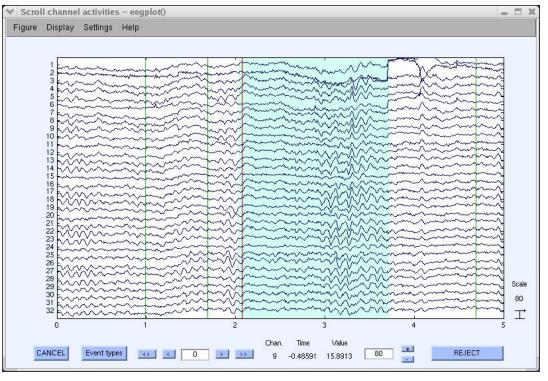
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File Edit Tools Plot	Datasets Help
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Import epoch info 🛛 🕞	epociis
Import event info 🛛 🗠	From Matlab array or ASCII file
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ILH Weights Dataset size (Mb)	Yes 14.9



Data info

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	Channe]	l locati	ons	No			
	ICA wei	ights		No			
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Scrolling data

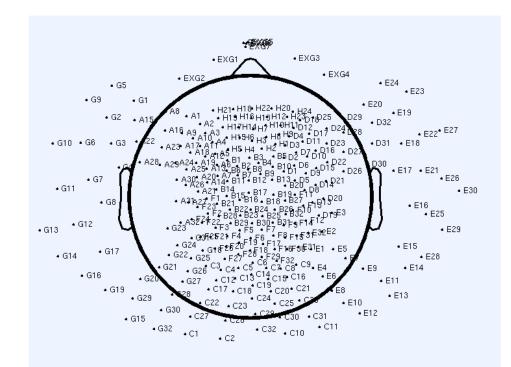


1. Importing channel location

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Import channel location

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1	Select epochs/events	75
	Copy current dataset	128
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1	Delete dataset(s)	No
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I	CA weights	Yes
D	ataset size (Mb)	14.9

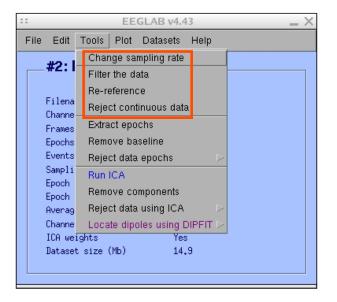


2. Edit, Re-reference, Resample, High pass filter data

Edit/select data

::	••• EEGLAB v4.43 _ X						
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Preprocessing data



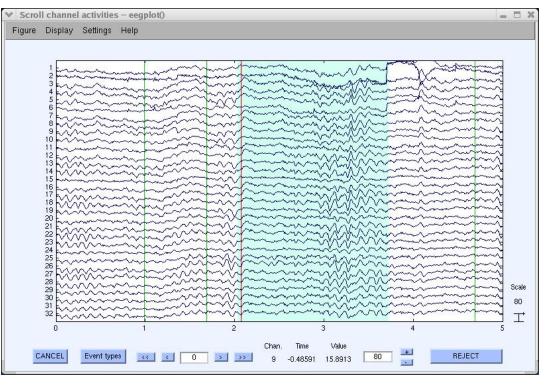
3. Reject artifacts in continuous data by visual inspection

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Data info

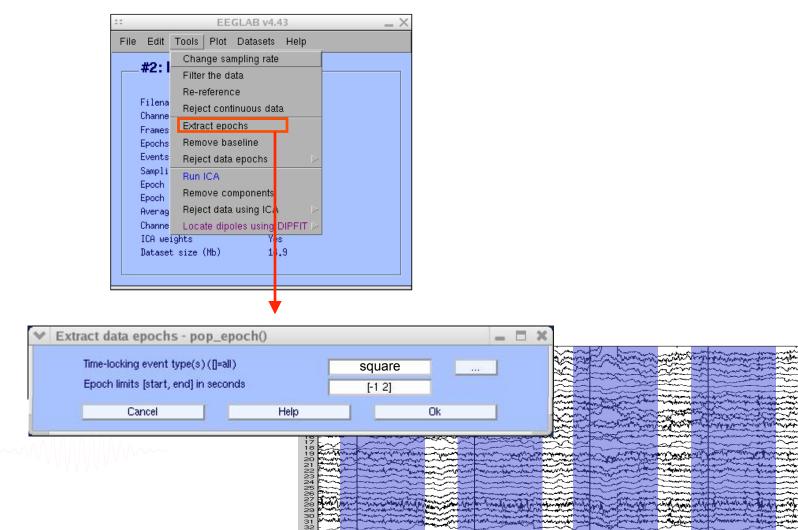
File Edi	t Tools Plot Datasets Help
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Reject portions of continuous data



4. Extract epochs from data & reject artifactual epochs

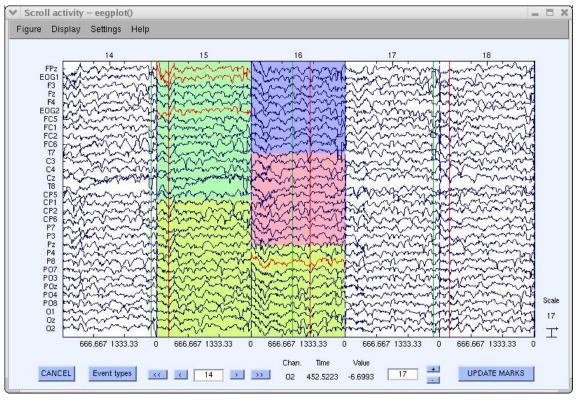
Preprocessing data



4. Extract epochs from data & reject artifactual epochs

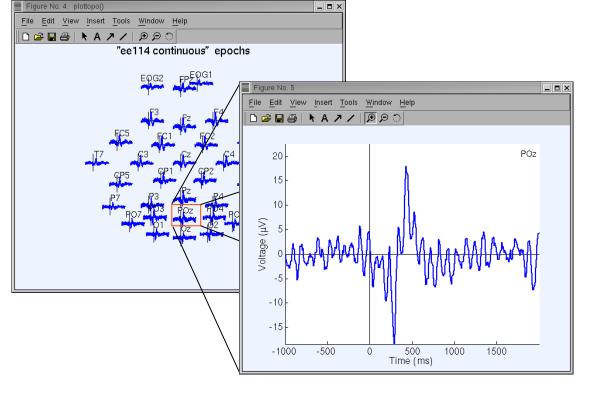
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		Sampli Epoch Epoch	Run Rem		mponents			Reject by inspection Reject extreme values	
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		Channe 100	Loca	ite dipo	oles using l	BESA	Þ	Reject by probability	
		ICA we Datase	Loca	ite dipo	les using l	DIPFIT	⊳	Reject by kurtosis	
		240400	Lapla	acian			\geq	Reject by spectra	
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			Filter	r the da	ata (IIR)		\geq	Reject marked epochs	

Different color = different rejection methods



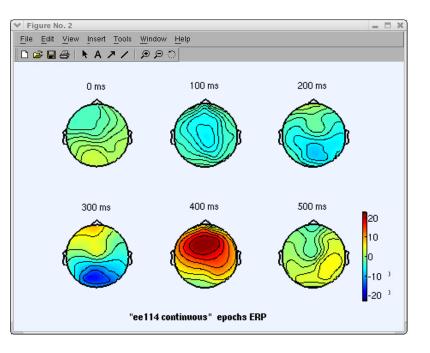
EEGLAB v4.43 $- \times$ File Edit Tools Plot Datasets Help Channel locations #1: EEG [Channel data (scroll) Channel spectra and maps Filename: eeg Channel properties Channels per H Channel ERP image Frames per epu Channel ERPs Epochs With scalp maps Events ERP map series In scalp array Sampling rate 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

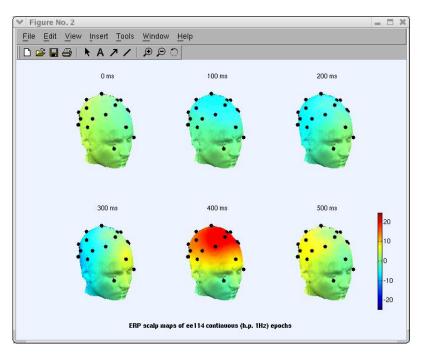
Plot ERP



Plot ERP map series

	EEGLAB v4.43	_ ×
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	Time-frequency transforms]

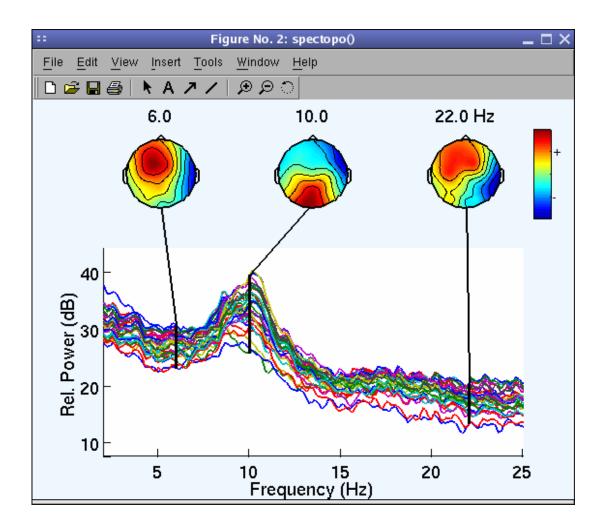




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Plot data spectrum and maps

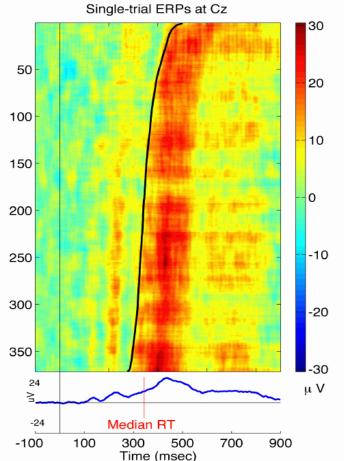
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	Ī	Time-frequency transforms		

Plot channel ERPimage



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

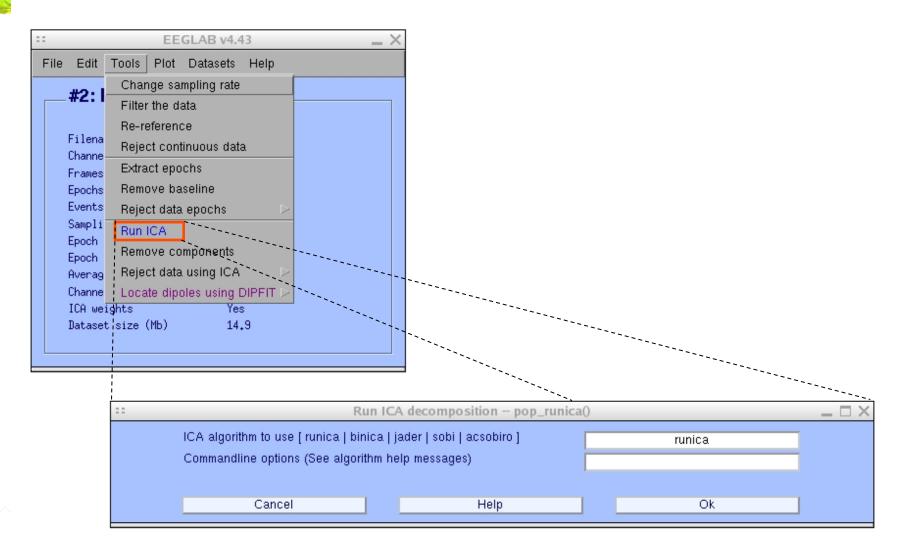
Multi-subjects

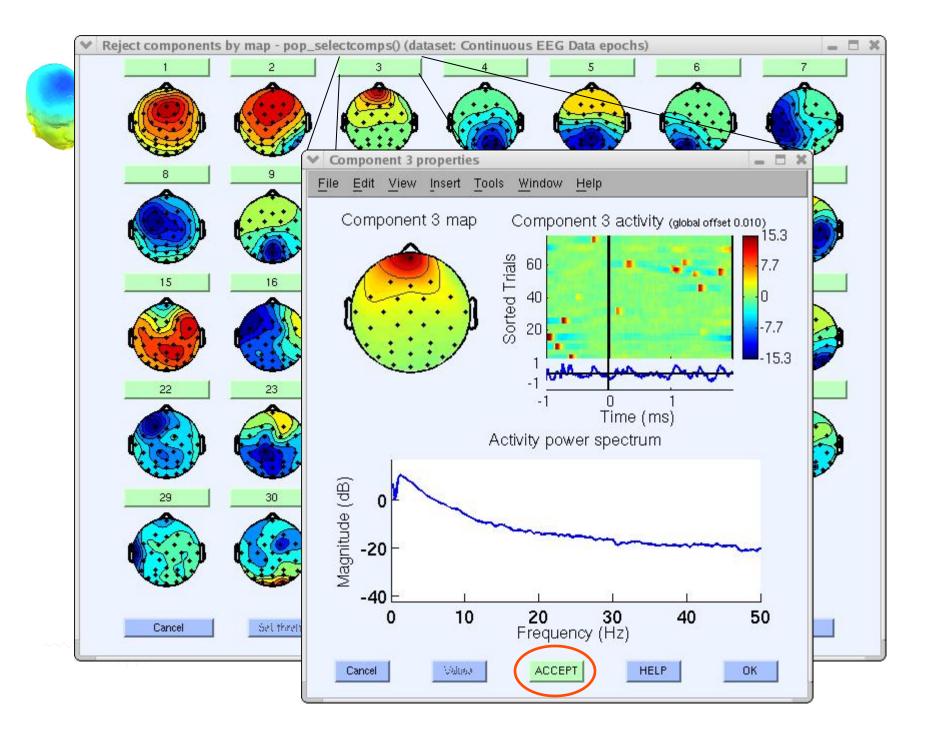
- 1. Build study
- 2. Pre-compute measures
- 3. Cluster components
- 4. Analyze clusters

Advanced analysis using scripting and EEGLAB command line functions

6. Perform ICA decomposition

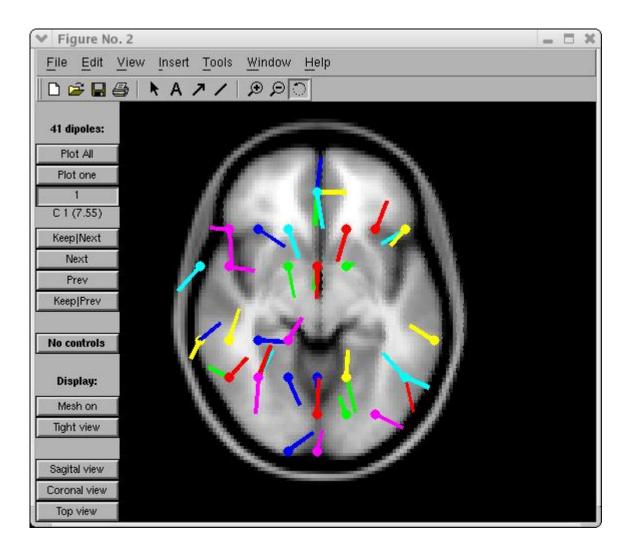
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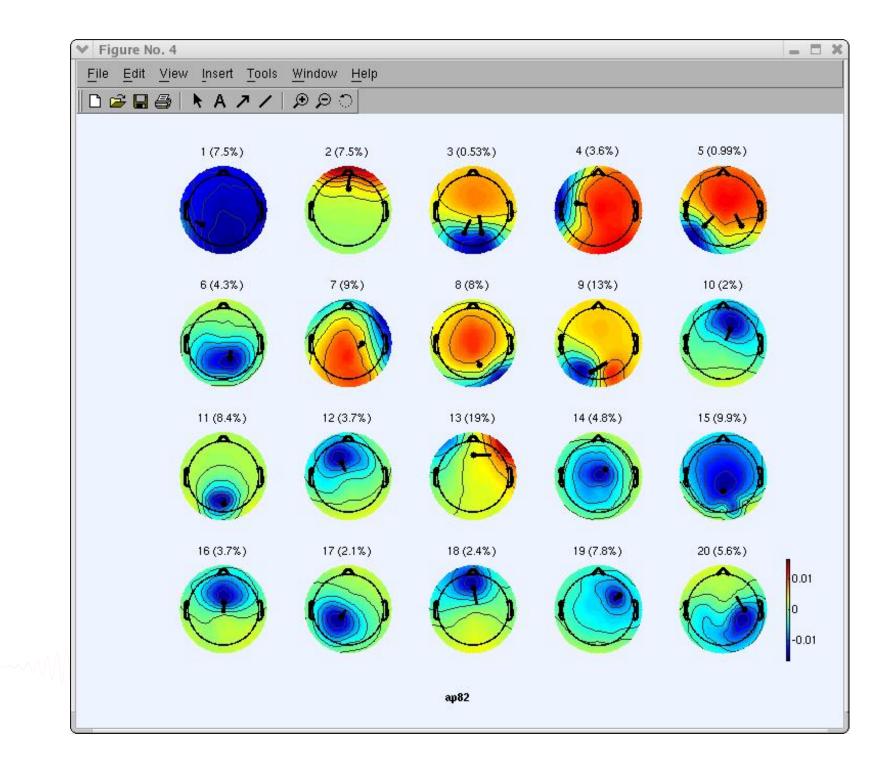




	EEGLAB v4.43	_ × _
File Edit	Tools Plot Datasets Help	
Filena Channe Frames Events Sampli Epoch Averag	Reject data epochs D Run ICA Remove components Reject data using ICA D	
Channe ICA we Datase	Locate dipoles using DIPFIT () ights Yes t size (Mb) 15.9	Autofit components Head model and settings
		Coarse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

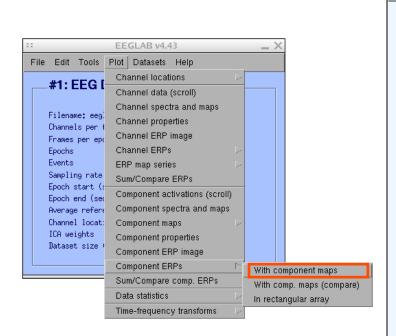


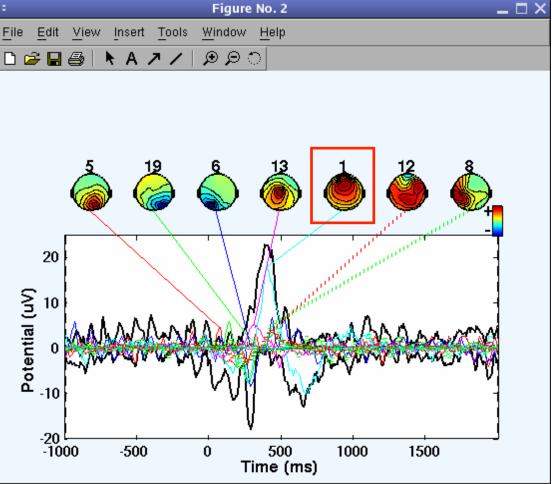




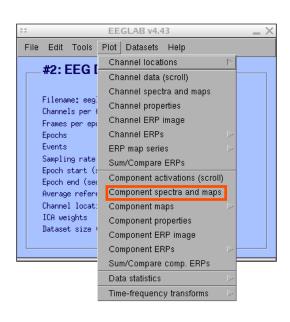
Component contribution to the ERP

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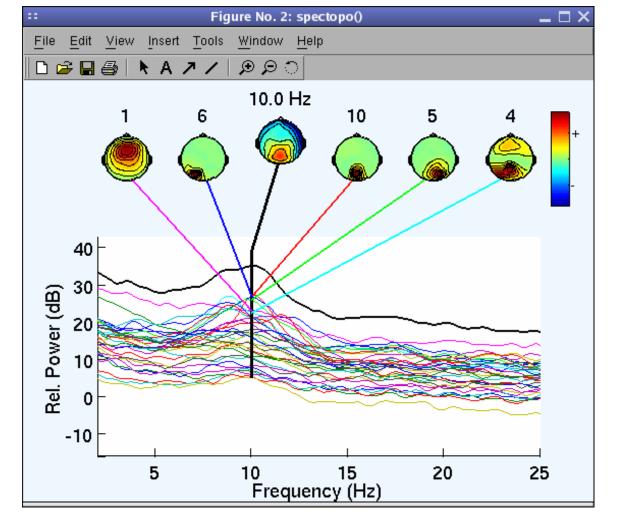




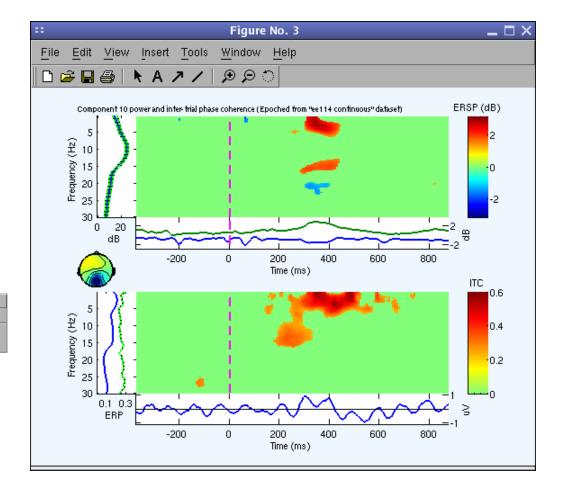
Component contribution to the EEG spectrum



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

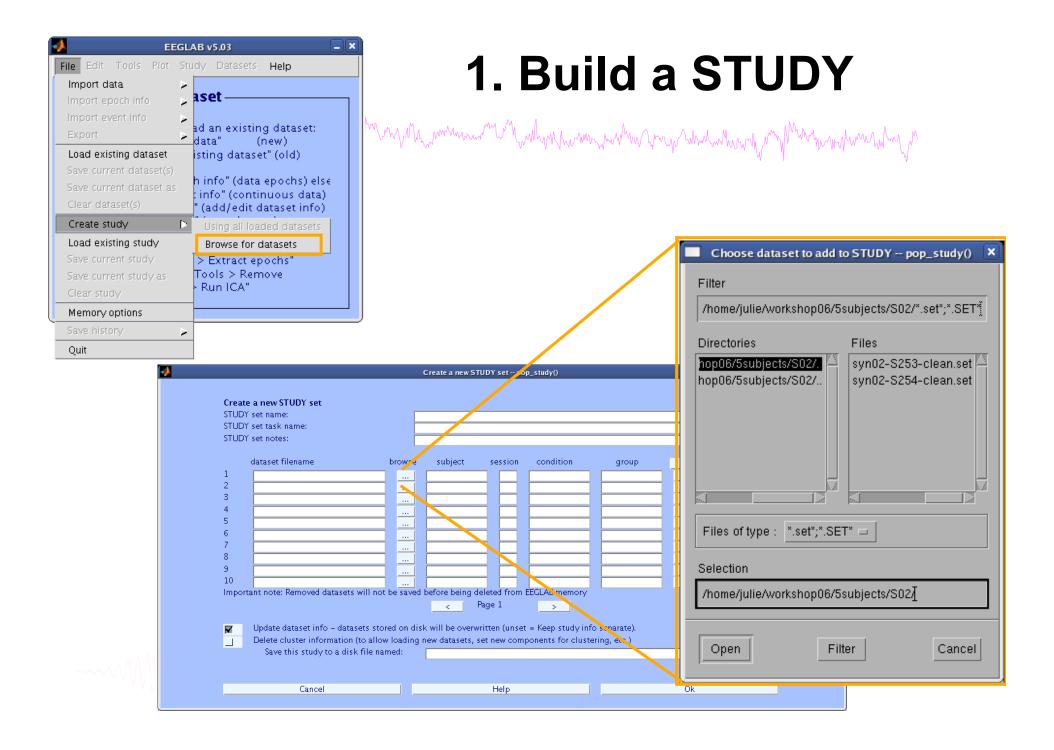
Single subject

- 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
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Use only specific datas	ets/trials	
	sociated with this STUDY design	



2. Pre-compute measures

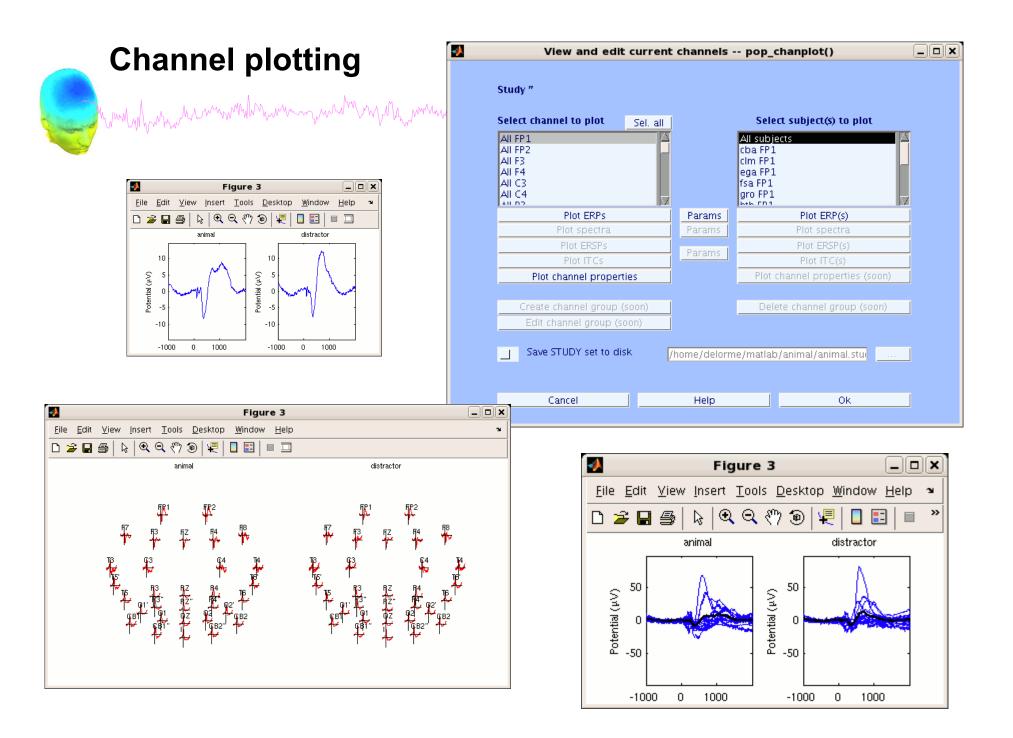
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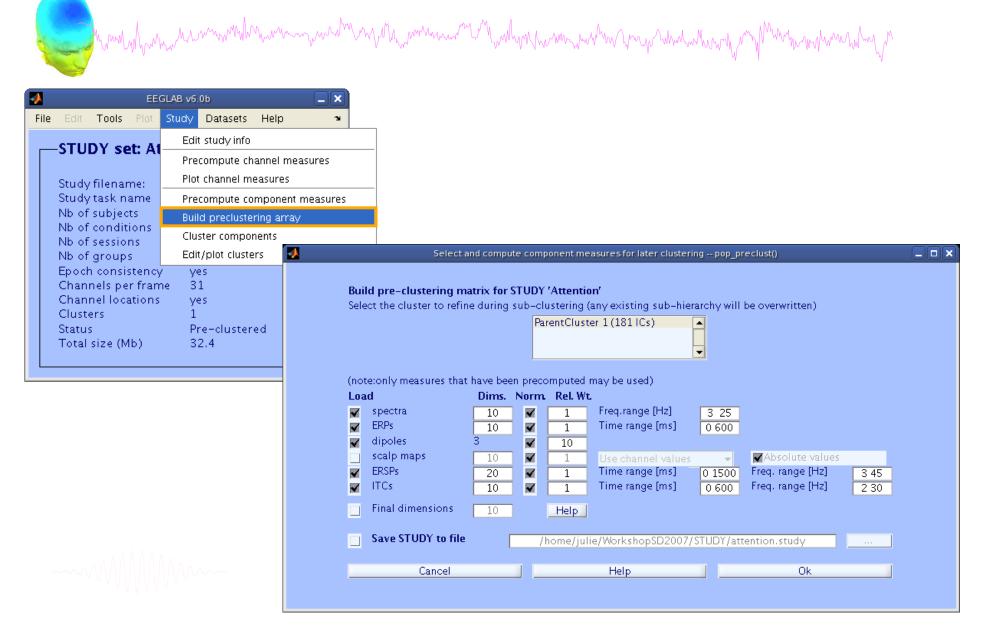
File Edit Tools Plot	Study Datasets Help
STUDY set:	Edit study info Select/Edit study design(s)
Study filename:s/data	Precompute channel measures
Study task name	Plot channel measures
Nb of subjects Nb of conditions Nb of sessions Nb of groups Epoch consistency	Precompute component measures Measure Product 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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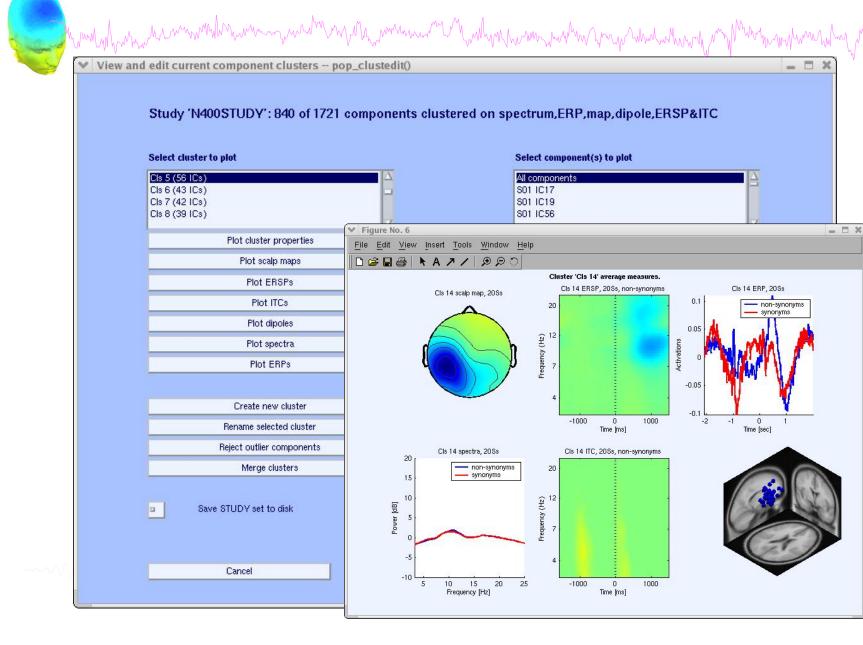
OOO Select and cor	npute component measures for later clustering pop_precomp()						
Pre-compute channel measures for STUDY " - 'STUDY.design 1'							
Channel list (default:all)							
Spherical interpolation	on of missing channels (performed after optional ICA removal below)						
Remove ICA artifactual 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						

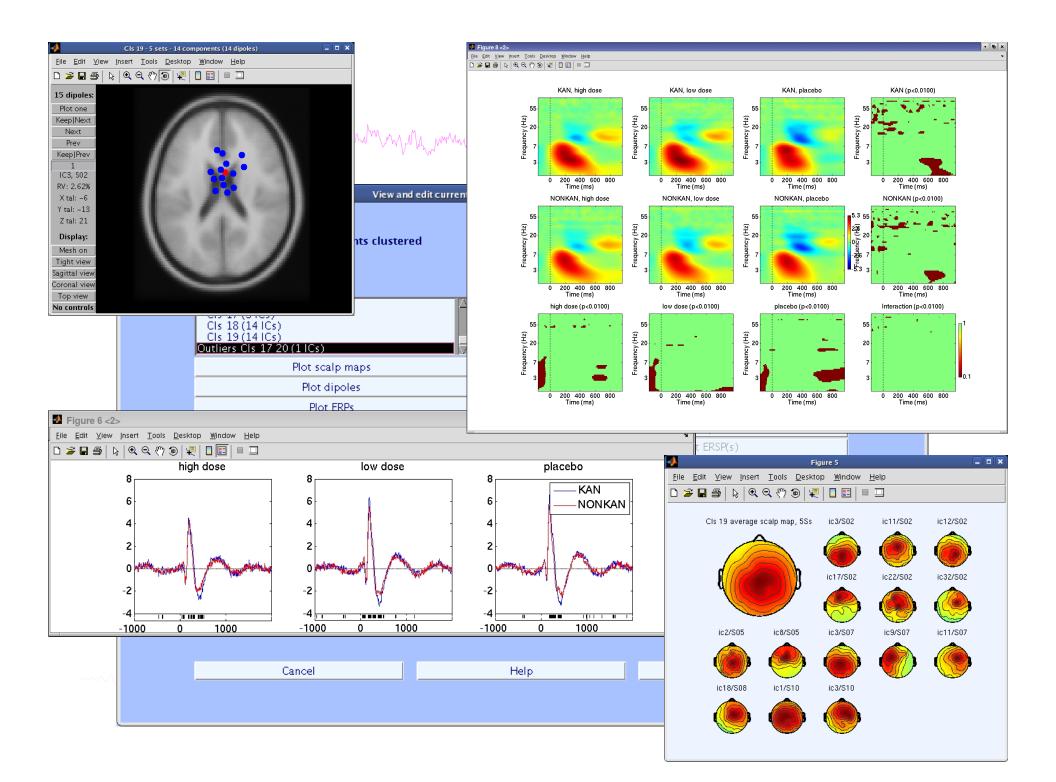


3. Cluster components



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
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 - Perform source localization of components
 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

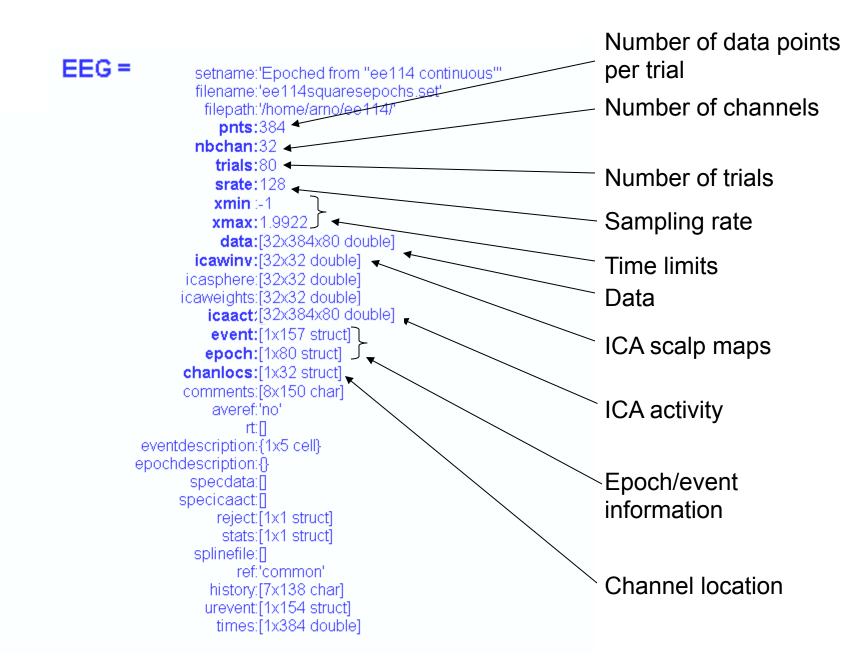
Multi-subjects

- 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(), ...



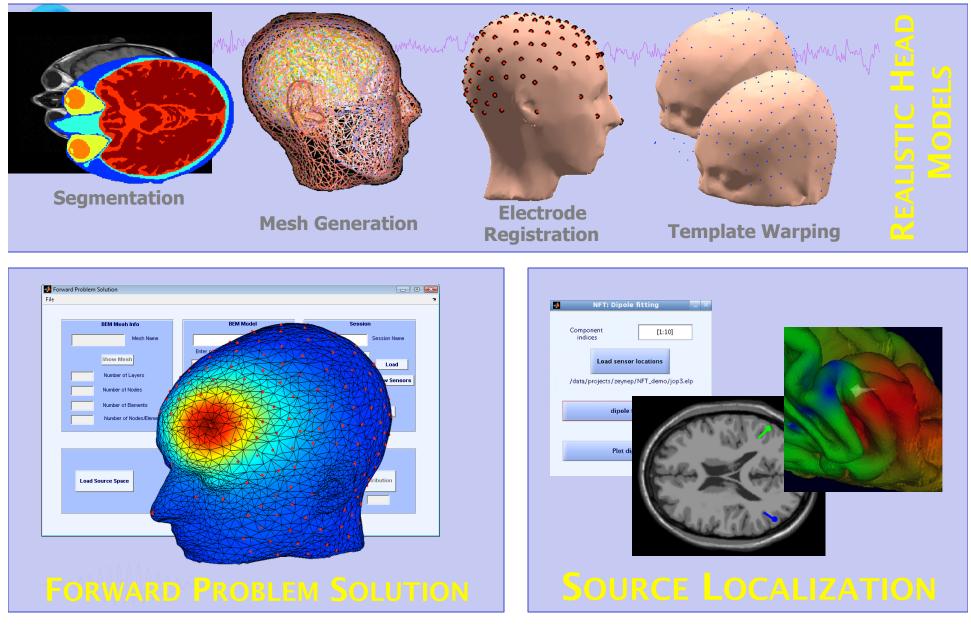
# Command line tools

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

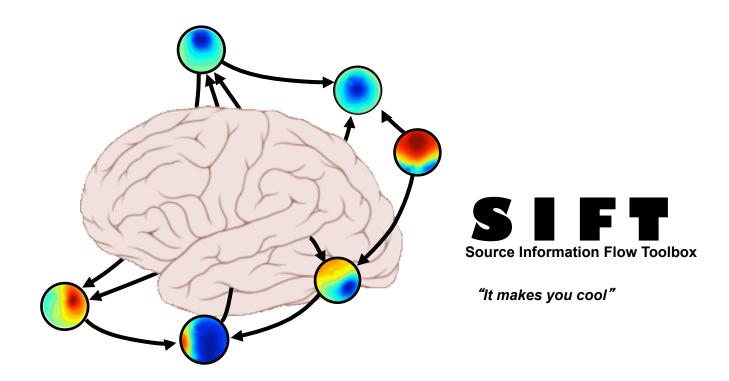
- Automated processing on groups of subjects (possibly on several processors).
- Richer options for plotting and processing functions (time-frequency decompositions, ...)
- Custom processing...

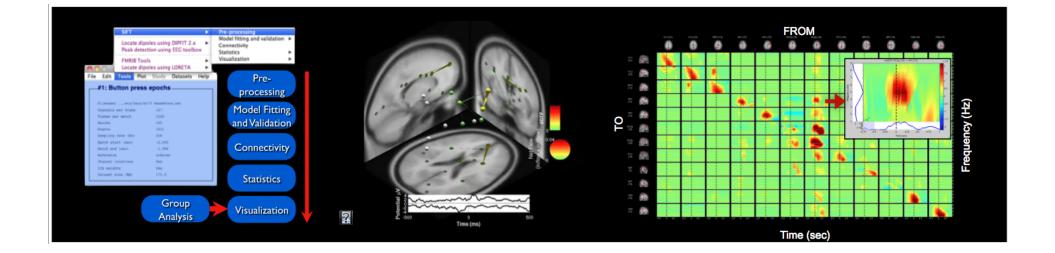


### NFT: Neuroelectromagnetic Forward Head Modeling Toolbox

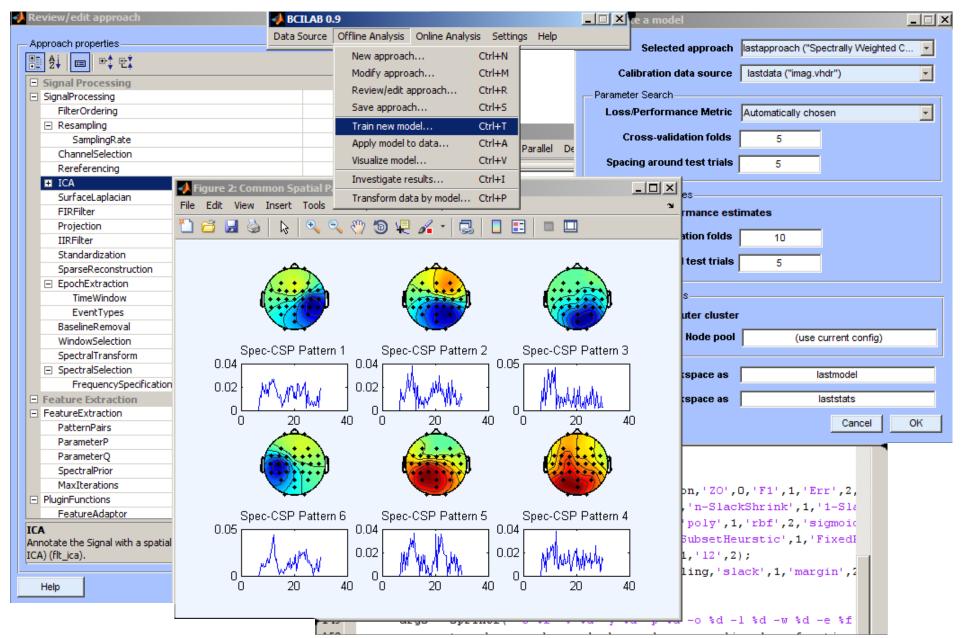


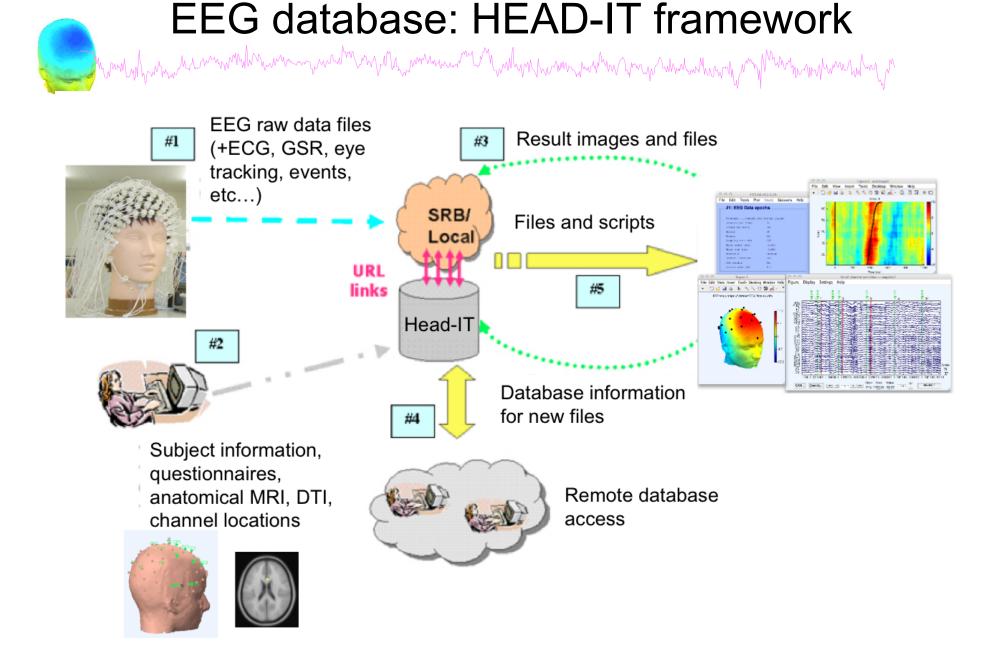
http://sccn.ucsd.edu/nft





## 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

#### **Beijing Workshop Program**

Purple lettering = lecture, Orange lettering = tutorial

```
Saturday, June 16
```

7:30 - 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--

10:30 – 11:15 -- ICA theory (Tzyy-Ping Jung)

11:15 – 12:00 -- Data import, artifact rejection and ICA decomposition (Julie Onton)

12:00-13:00 Lunch

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

13:00 – 14:00 -- Evaluating ICA components (Julie Onton)

14:00 – 15:00 -- Time-Frequency decompositions and practicum (Tim Mullen)

--Break --

15:30 - 16:30 -- SIFT toolbox: Source information flow and granger causality tools (T. Mullen)

16:30 – 17:30 -- Using the SIFT toolbox (Tim Mullen)

17:30 – 19:00 -- Data and helpers available

19:00 Dinner

Sunday, June 17th

7:30 - 8:30 Breakfast

Source Localization

8:30 – 9:00 -- Forward and inverse EEG source modeling - (Scott Makeig)

9:00 – 9:30 -- Using the NFT and Dipfit plug-ins (Julie Onton)

9:30 – 10:00 -- Why and how to cluster independent EEG component processes (Scott Makeig) -- Break--

**Component Clustering** 

10:30 – 11:00 -- Creating EEGLAB studies and study designs (Arnaud Delorme)

11:00 – 12:00 -- Independent Component Clustering (Arnaud Delorme)

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

#### Processing multiple subjects using STUDY tools

13:00 – 13:30 -- Trial-by-trial data visualization and scripting (Julie Onton)

13:30 – 14:30 -- Plotting measures and computing statistics for EEGLAB studies (Arnaud Delorme)

- 14:30 15:30 -- Scripting for EEGLAB studies (Arnaud Delorme)
- 15:30 19:00-- Practicum on datasets and results presentation

19:00 Dinner

#### Monday, June 18th

7:30-8:30 -- Breakfast

8:30 - 9:00 -- Mining event-related brain dynamics II (Scott Makeig)

9:00 – 9:30 -- The near future of wireless EEG and mobile brain/body imaging (Tzyy Ping Jung)

9:30 – 10:00 -- Building and publishing EEGLAB plug-ins (Arnaud Delorme)

-- Break--

10:30 – 11:30 -- Brain-computer interface (BCI) design: Theory and practice (Christian Kothe)

11:30 – 12:30 -- Using BCILAB (Christian Kothe)

- 12:30 13:30 Lunch
- 14:00 17:30 Excursion

17:30 – 18:30 -- Final discussion (Makeig, Jung, Delorme and all)

18:30 workshop ends



# **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. First EEGLAB Workshop

University of CA San Diego La Jolla, California, Oct. 28-30, 2004 following the Society for Neuroscience meeting in San Diego



# Workshops

Third EEGLAB Workshop Singapore, Nov. 15-18, 2006

#### Second EEGLAB Workshop

Porto, Portugal, Sept. 17-19, 2005 preceeding the SPR meeting in Lisbon





**12<sup>th</sup> EEGLAB Workshop** UCSD, San Diego, Nov 18-22, 2010



#### Fourth EEGLAB Workshop

Aspet (pyrénées), France, June 26-29, 2007

