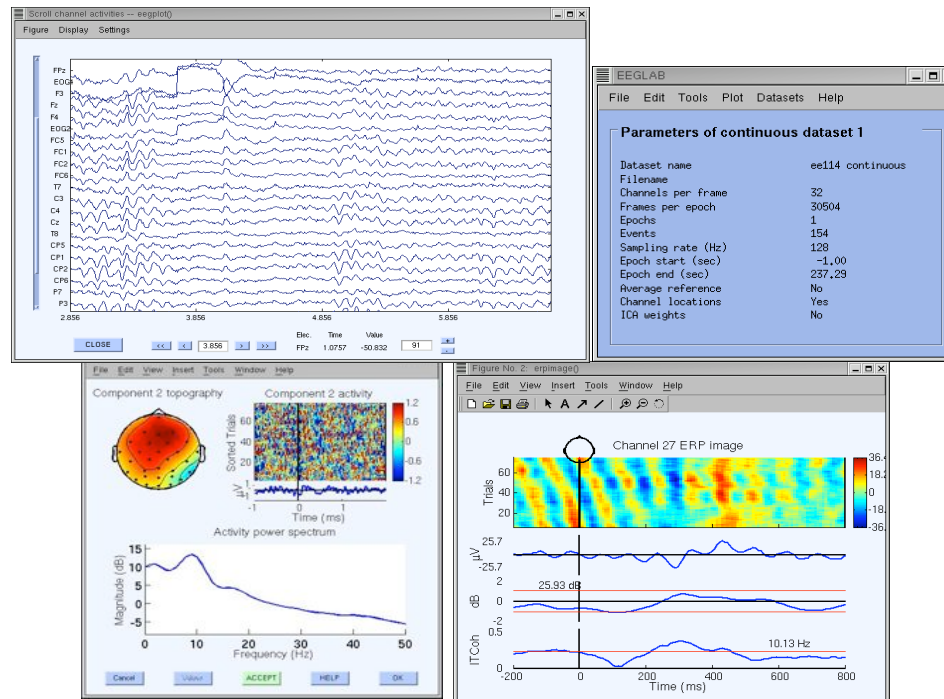


# EEGLAB

An open-source signal processing environment for Matlab



<http://sccn.ucsd.edu/eeglab>

# EEGLAB History

- 1993 – ERSP (Makeig)
- 1995 – Infomax ICA for EEG (Makeig, Bell, Jung, Sejnowski)
- 1997 - EEG/ICA Toolbox (cnl.salk.edu), ITC & ERC
- 1999 - ERP-image plots (Jung & Makeig)
- 2000 - Toolbox GUI design (Delorme)
- 2002 - EEGLAB (sccn.ucsd.edu)
- 2004 - NIH support, and (Delorme & Makeig) reference paper
- 2004 - 1<sup>st</sup> EEGLAB workshop (UCSD, La Jolla, California)
- 2004 - 1<sup>st</sup> EEGLAB plug-ins
- 2005 – Workshops in Porto (Portugal) and Libon (SPR)
- 2006 – Workshop in Singapore
- 2006 - 1<sup>st</sup> STUDY structure and component clustering tools
- 2007 - Workshops in Aspet (France), La Jolla (California), Santiago (Chile)
- 2008 - NIH support renewed...
- 2009 – NFT – Neuroelectromagnetic Forward Head Modeling Toolbox
- 2009 - Workshops in Bloomington (Indiana), Aspet (France),  
La Jolla (California), Sydney (Australia)
- 2009 – DataRiver/Producer - experimental environment control
- 2010 - HeadIT database tied to EEGLAB

## EEGLAB downloads for 20/06/2007

Total count is 34

Username	Email	Comments
Russia	@mail.ru	eeg, erp, bci
Company	@nexstim.com	EEG developer
Indonesia	@tf.itb.ac.id	Brain Computer Interface
Finland	@psyka.jyu.fi	
Australia	@newcastle.edu.au	clinical psychophysiology research
La Jolla	@gmail.com	Cogneuro EEGLab is great!
China?	@yahoo.com	LFP in DBS patients
US Gov	@pnl.gov	
US EDU	@ethz.ch	research purposes to music stimuli
US EDU	@wjh.harvard.edu	Neuroscience
US EDU	@umich.edu	infection ERP
Switzerland	@student.ethz.ch	
Sweden	@neuro.gu.se	EEG
Germany	@med.uni-muenchen.de	
China?	@163.com	Signal Processing
China	@sina.com	ica
Finland	@helsinki.fi	cognitive brain research
Spain	@ugr.es	
Netherlands	@sdf.nl	dfg
Company?	@tom.com	BCI
?	painfulresult@com	
France	@hotmail.fr	Biomedical engineering movement-related cortical potentials brain-computer interfaces

- ~200 EEGLAB downloads a week
- ... to at least 90 country domains
- > 3,500 on the 'eeglablist' mailing list
- Over 20 EEGLAB plug-ins available

# EEGLAB Workshop La Jolla 2007

90 participants

- Canada
- USA

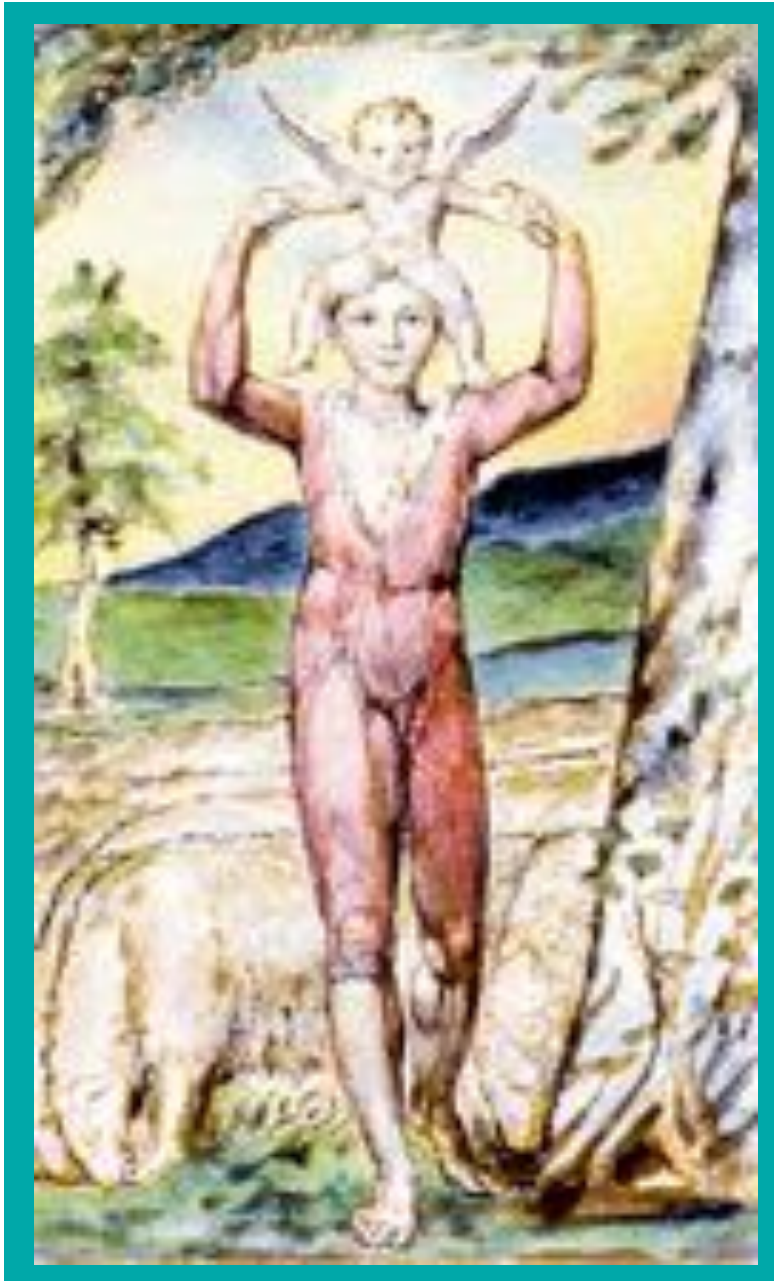
- Norway
- Ireland
- England

- Germany
- Austria
- Italy

- Japan
- Taiwan
- S. Korea
- Australia

Chile





# Mining Event-Related Brain Dynamics



**Scott Makeig**

Institute for Neural Computation  
University of California San Diego

University of Indiana  
April, 2009

# Active Human Agency

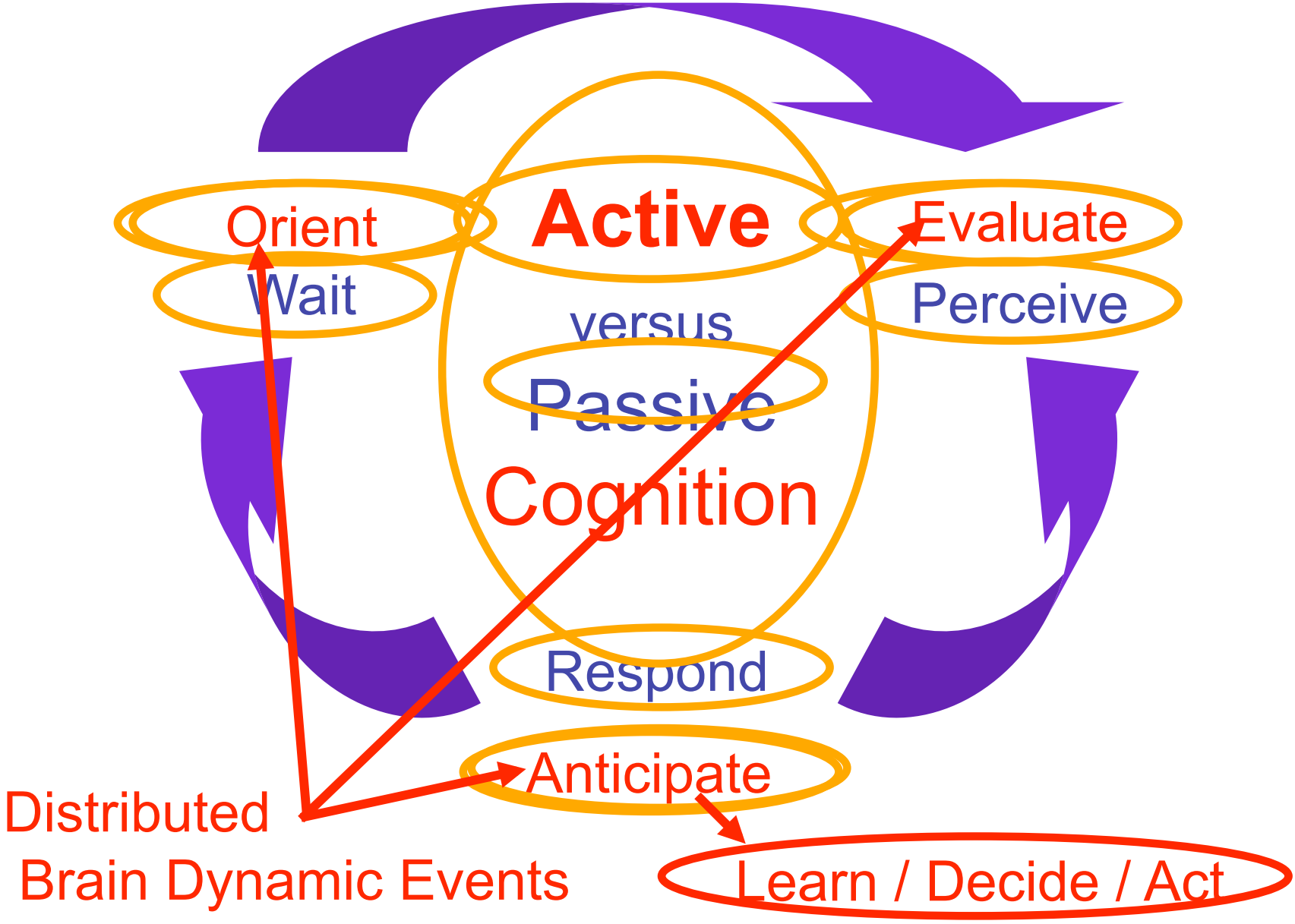
The brain responds  
to the challenge of each moment

constrained by  
its **past** impressions,

aligned to  
its **current** goals, needs & desires,

and focused on optimizing the  
**future results** of its behavior...

# Human Agency



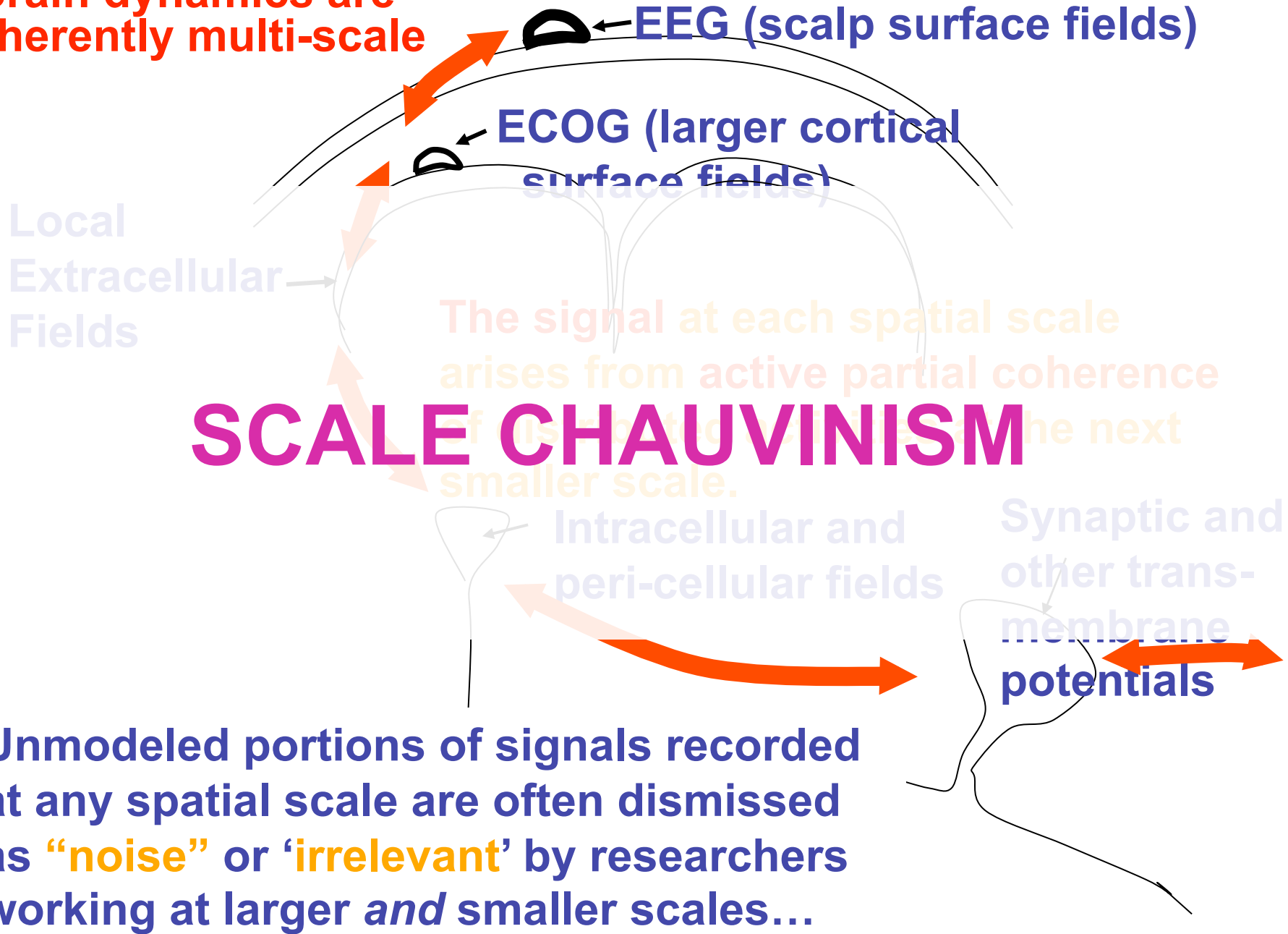


A dark field of galaxies, showing numerous distant galaxies in various colors (yellow, orange, blue, white) scattered across a black background. The text "What is EEG / LFP?" is overlaid in the center in a bright yellow font.

# What is EEG / LFP?



Brain dynamics are inherently multi-scale



EEG (scalp surface fields)

ECOG (larger cortical surface fields)

Local Extracellular Fields

The signal at each spatial scale arises from active partial coherence of its constituent fields at the next smaller scale.

# SCALE CHAUVINISM

Intracellular and peri-cellular fields

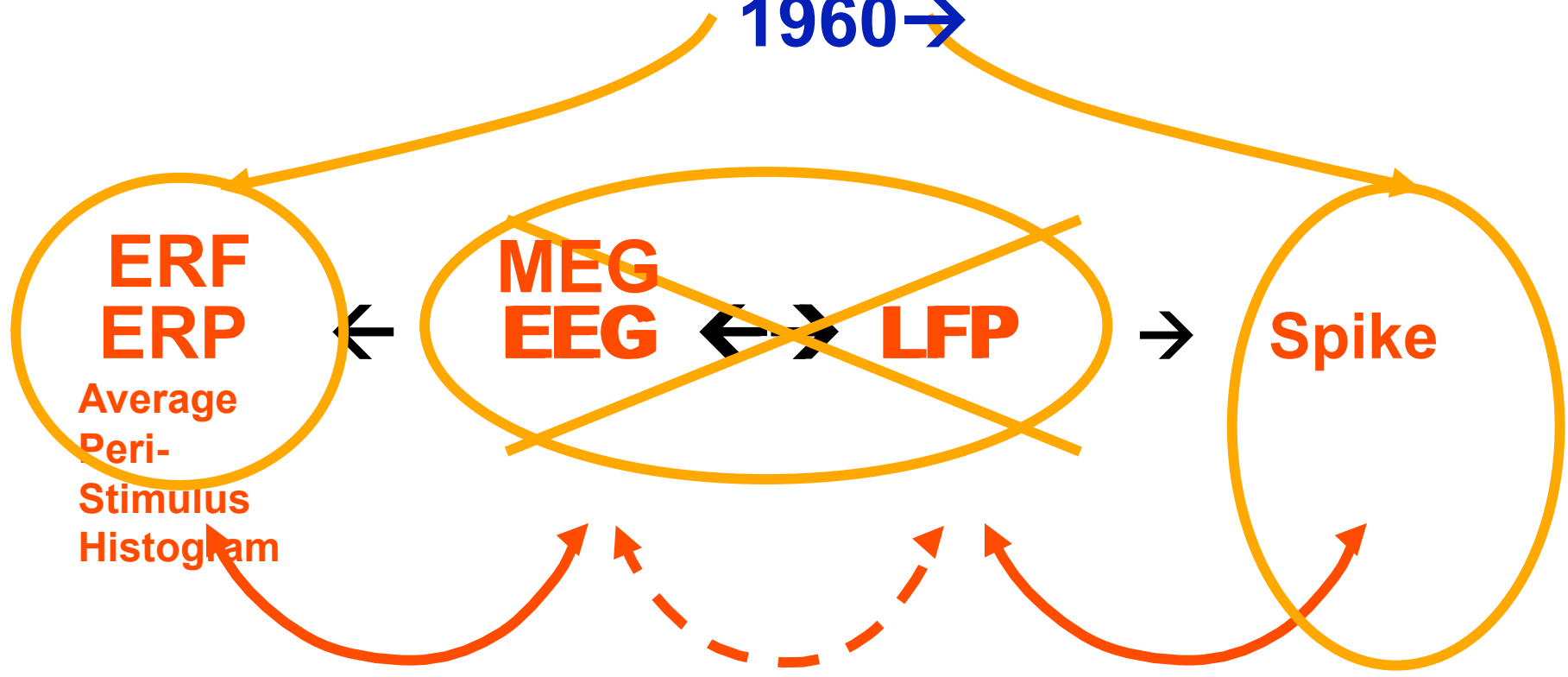
Synaptic and other trans-membrane potentials

Unmodeled portions of signals recorded at any spatial scale are often dismissed as "noise" or 'irrelevant' by researchers working at larger *and* smaller scales...

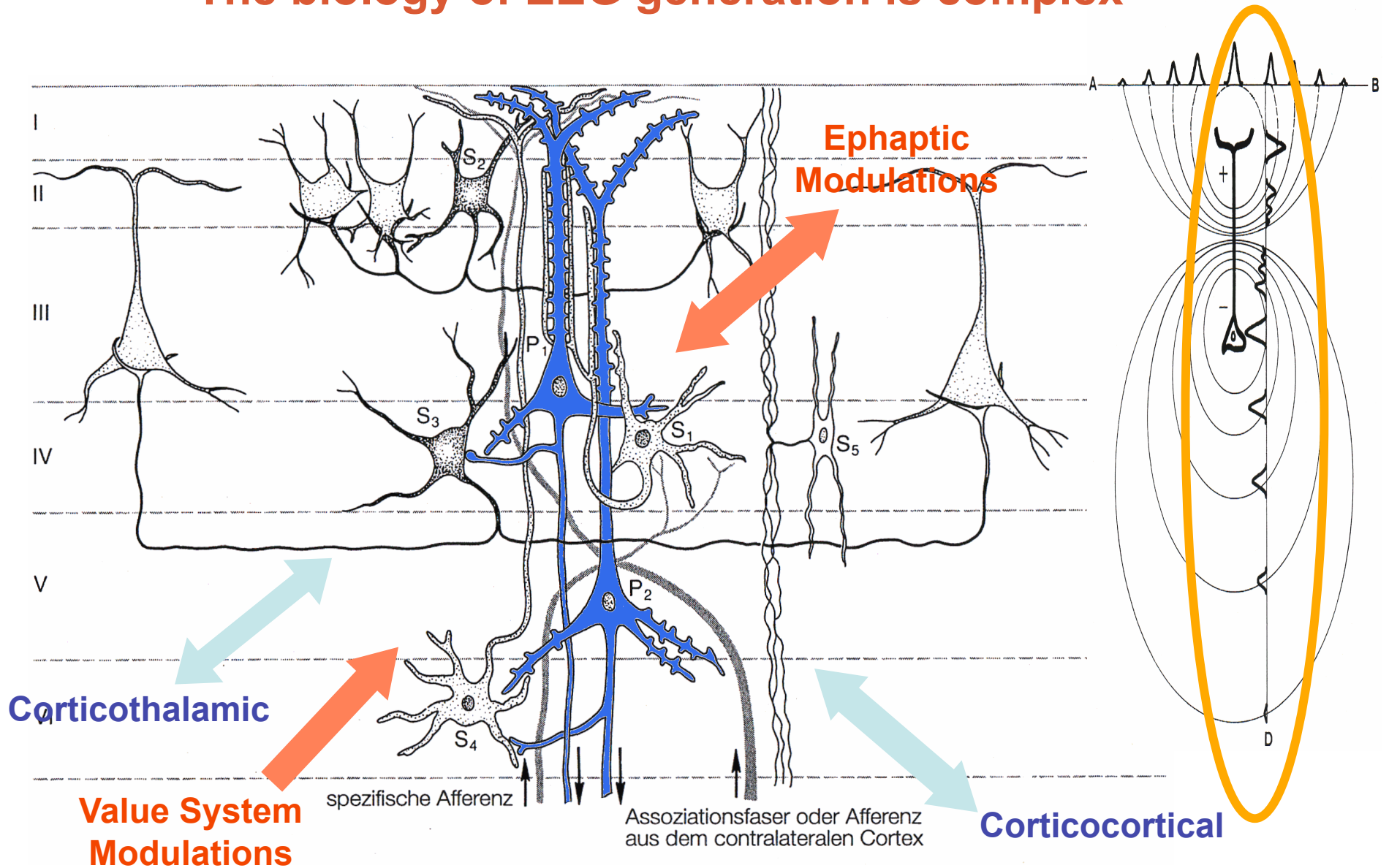
# Brain Electrophysiology

## Response Averaging

1960 →

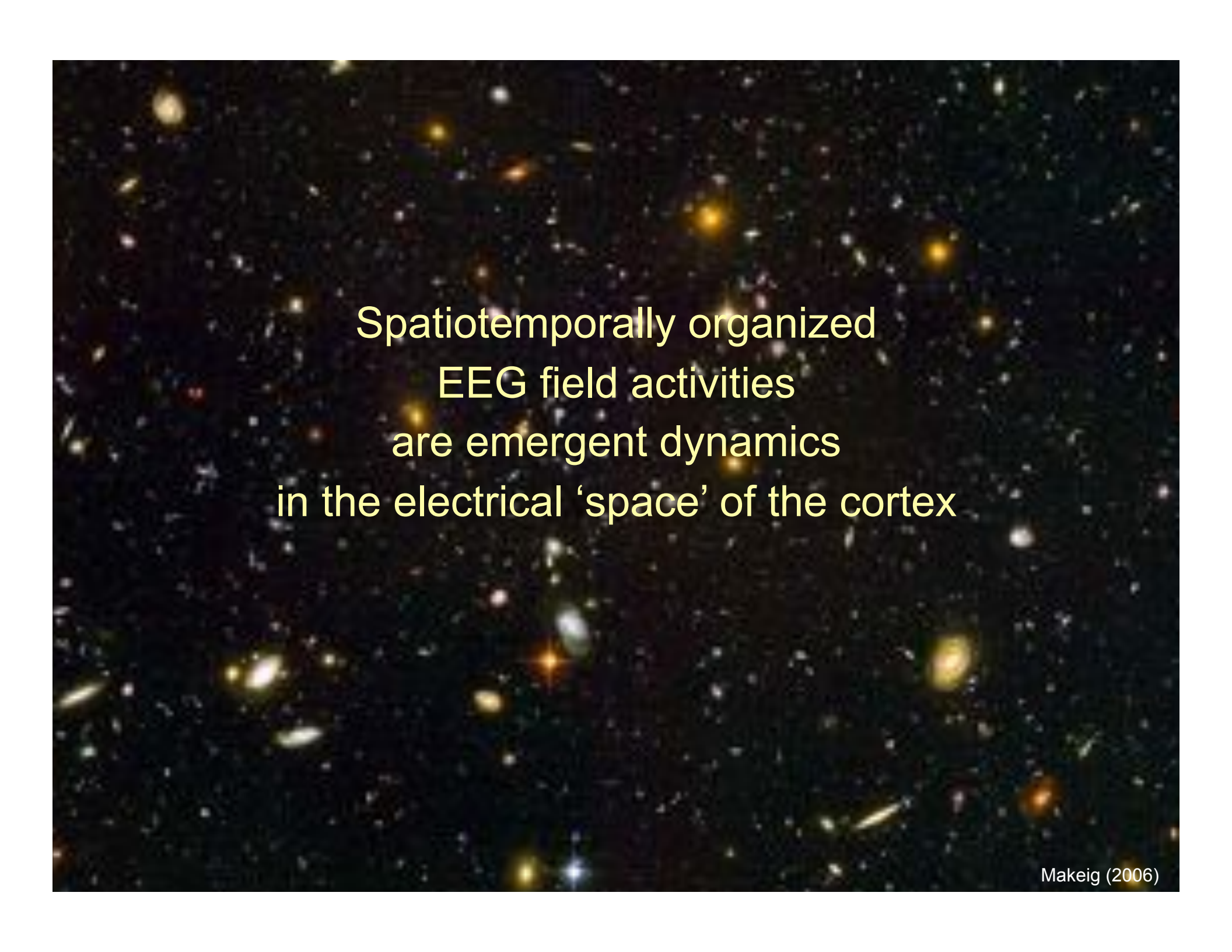


# The biology of EEG generation is complex





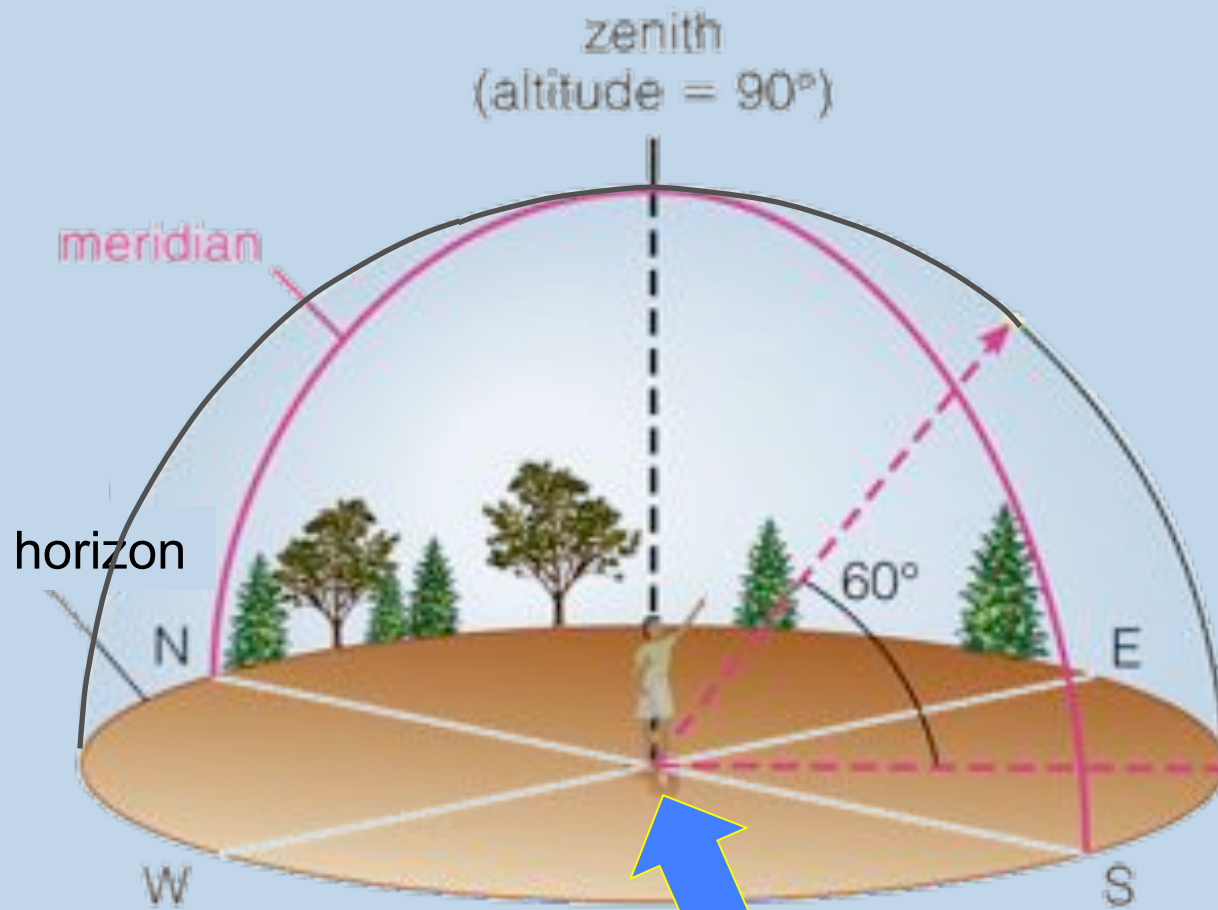
- **Phase cones (Freeman)**
- **Avalanches (Plenz)**

A dark field of stars and galaxies, serving as a background for the text. The stars are of various colors, including yellow, orange, and blue, and are scattered across the dark space. Some galaxies are visible, appearing as bright, elongated structures.

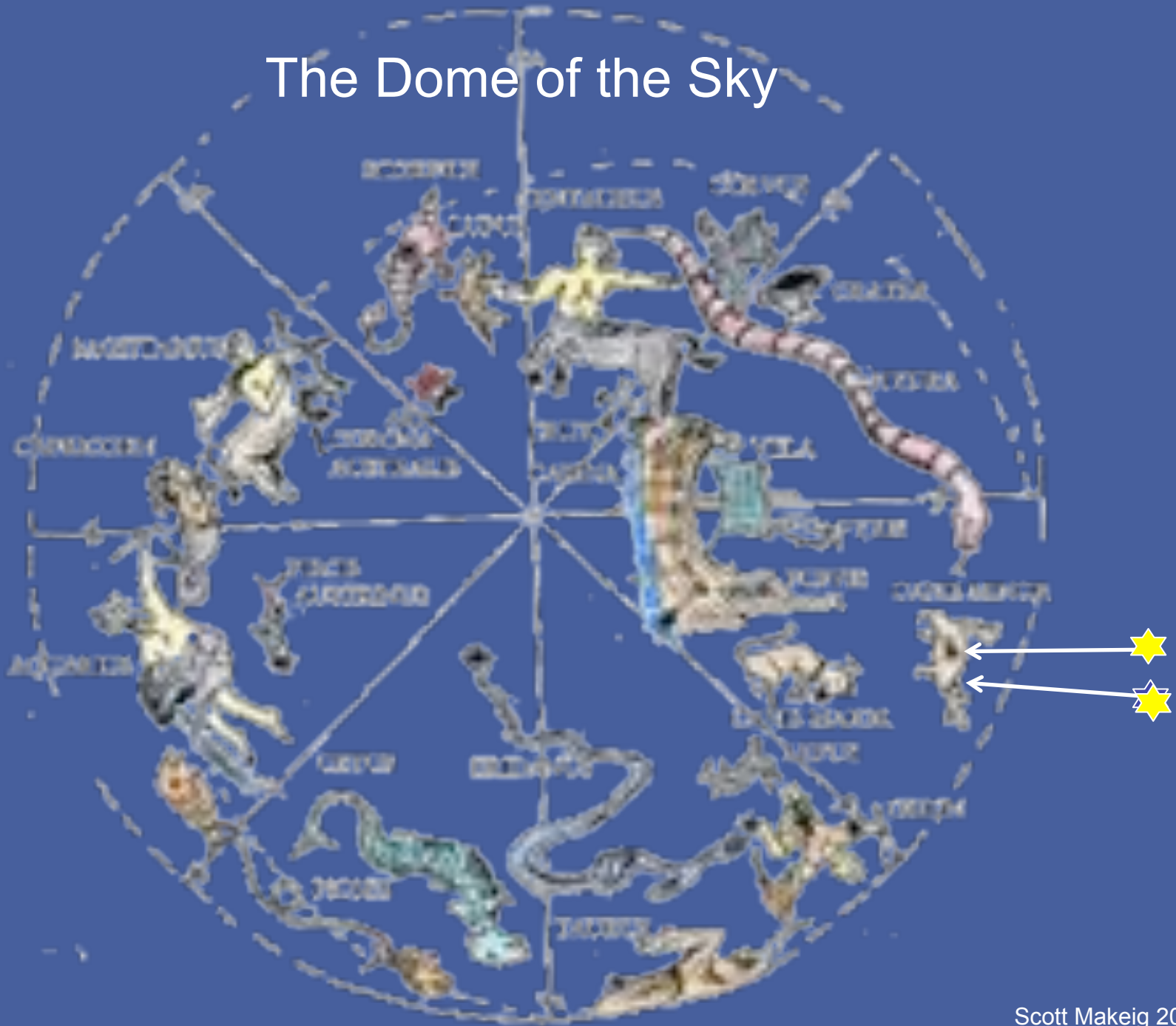
Spatiotemporally organized  
EEG field activities  
are emergent dynamics  
in the electrical 'space' of the cortex



# The Dome of the Sky



# The Dome of the Sky







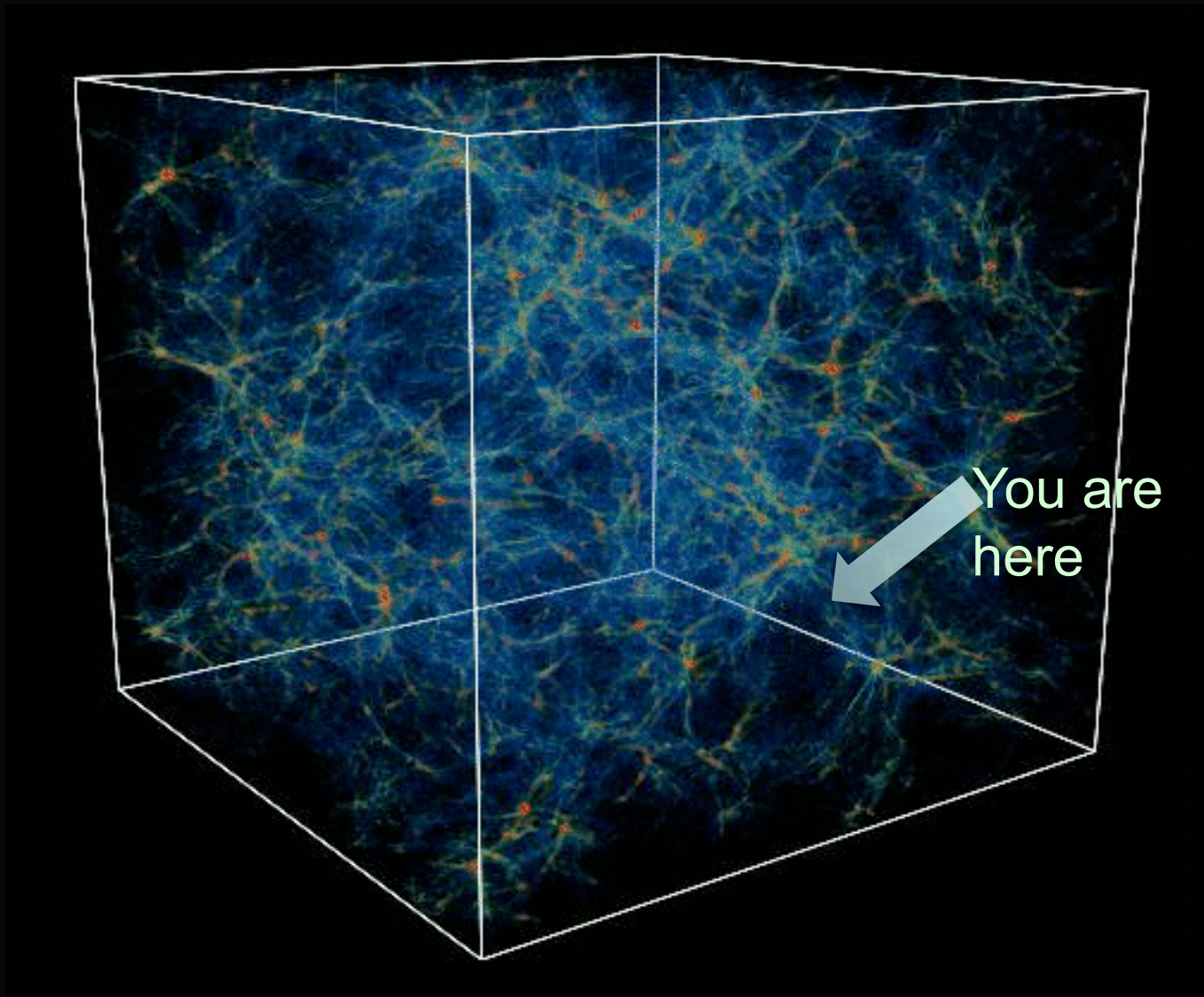
# The Dome of the Sky?



Scott Makeig 2008

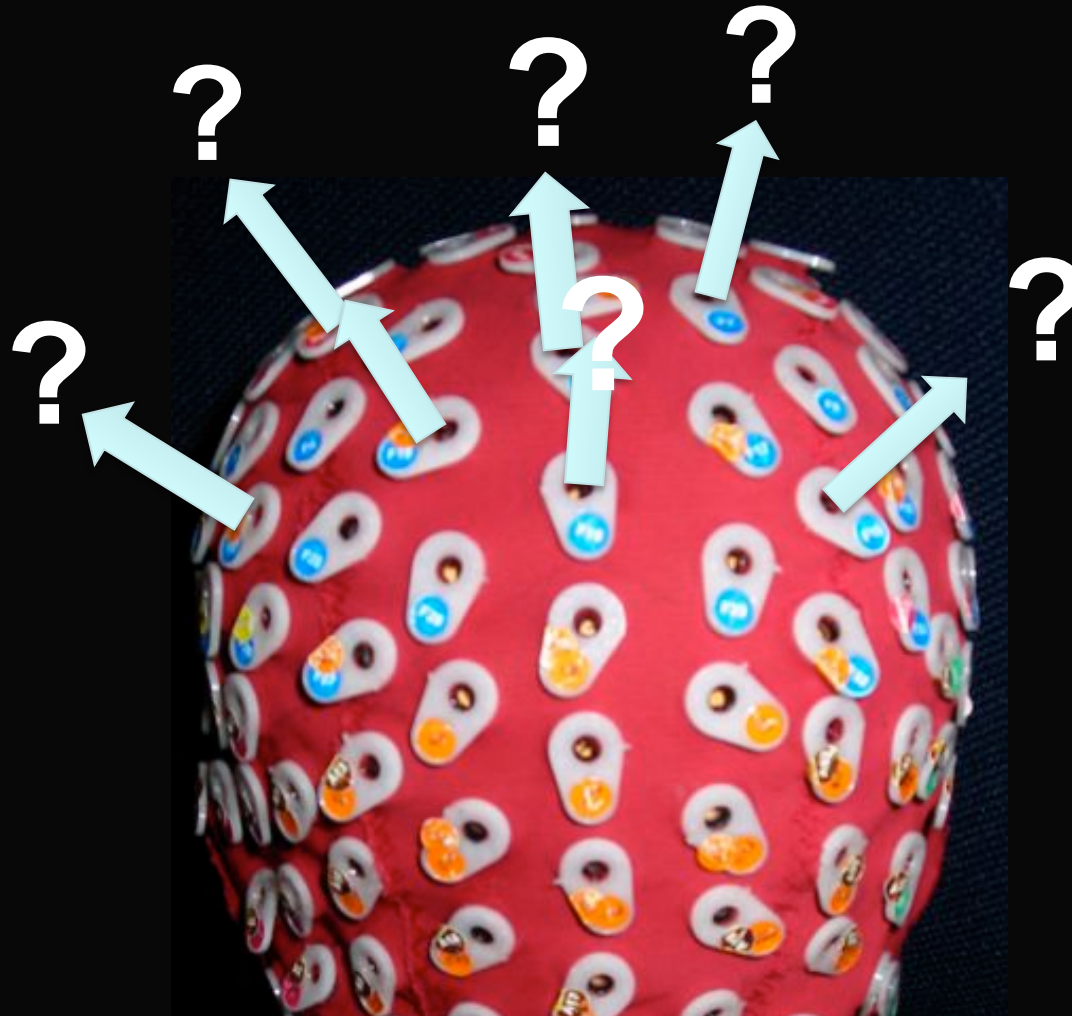


# The Dome of the Sky



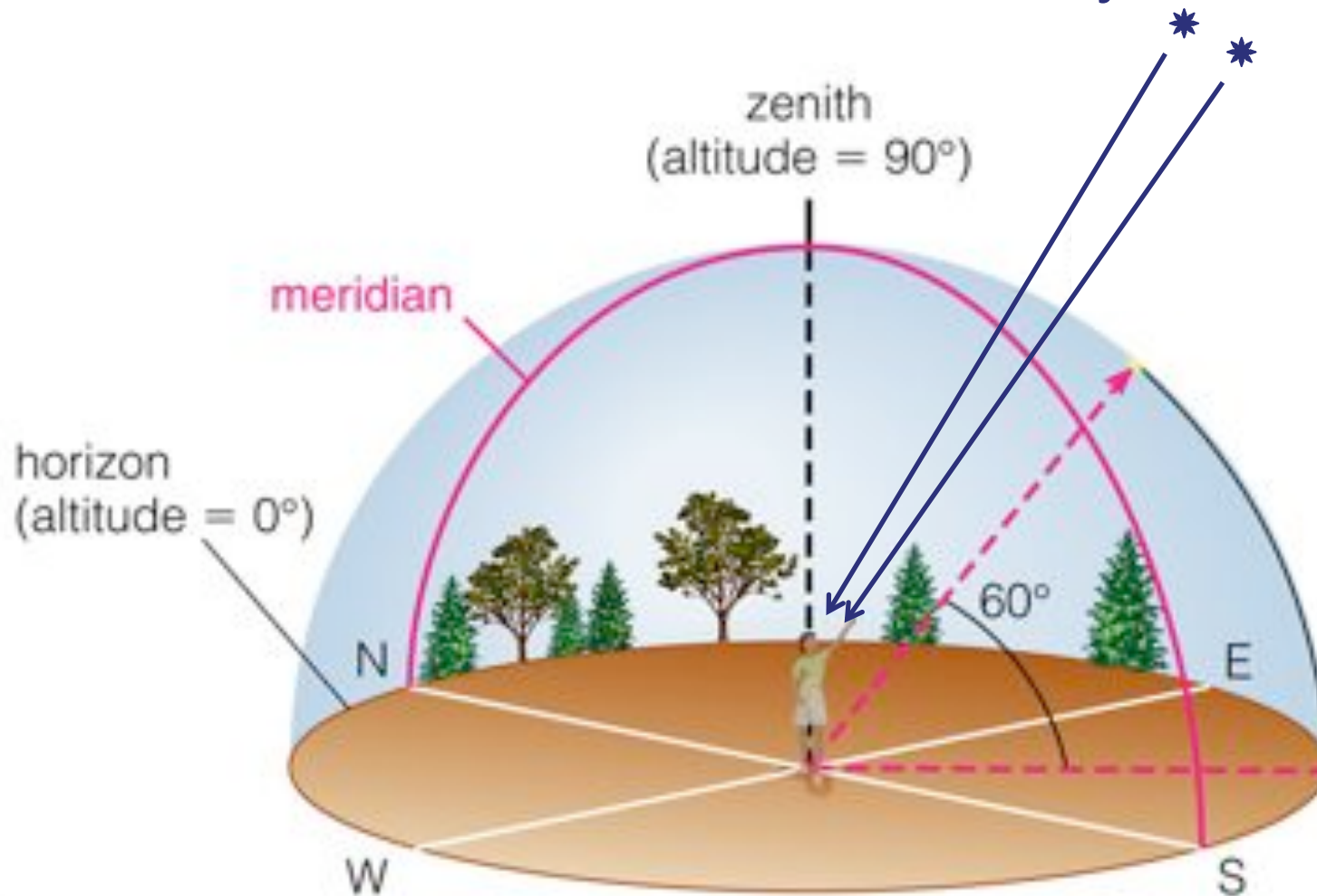


# The Dome of the Scalp?



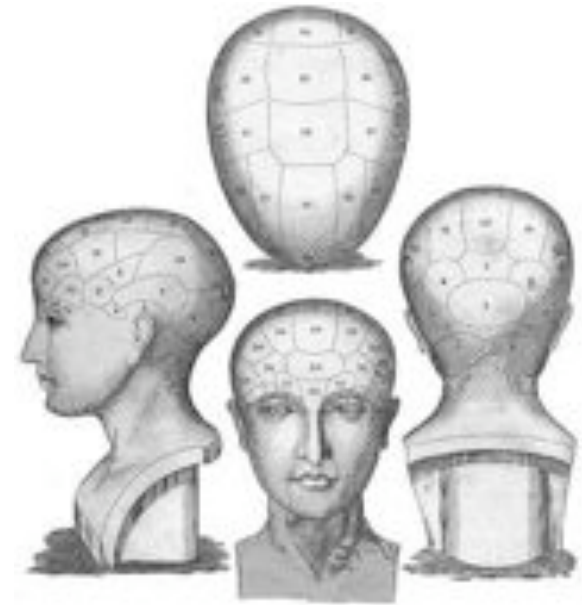
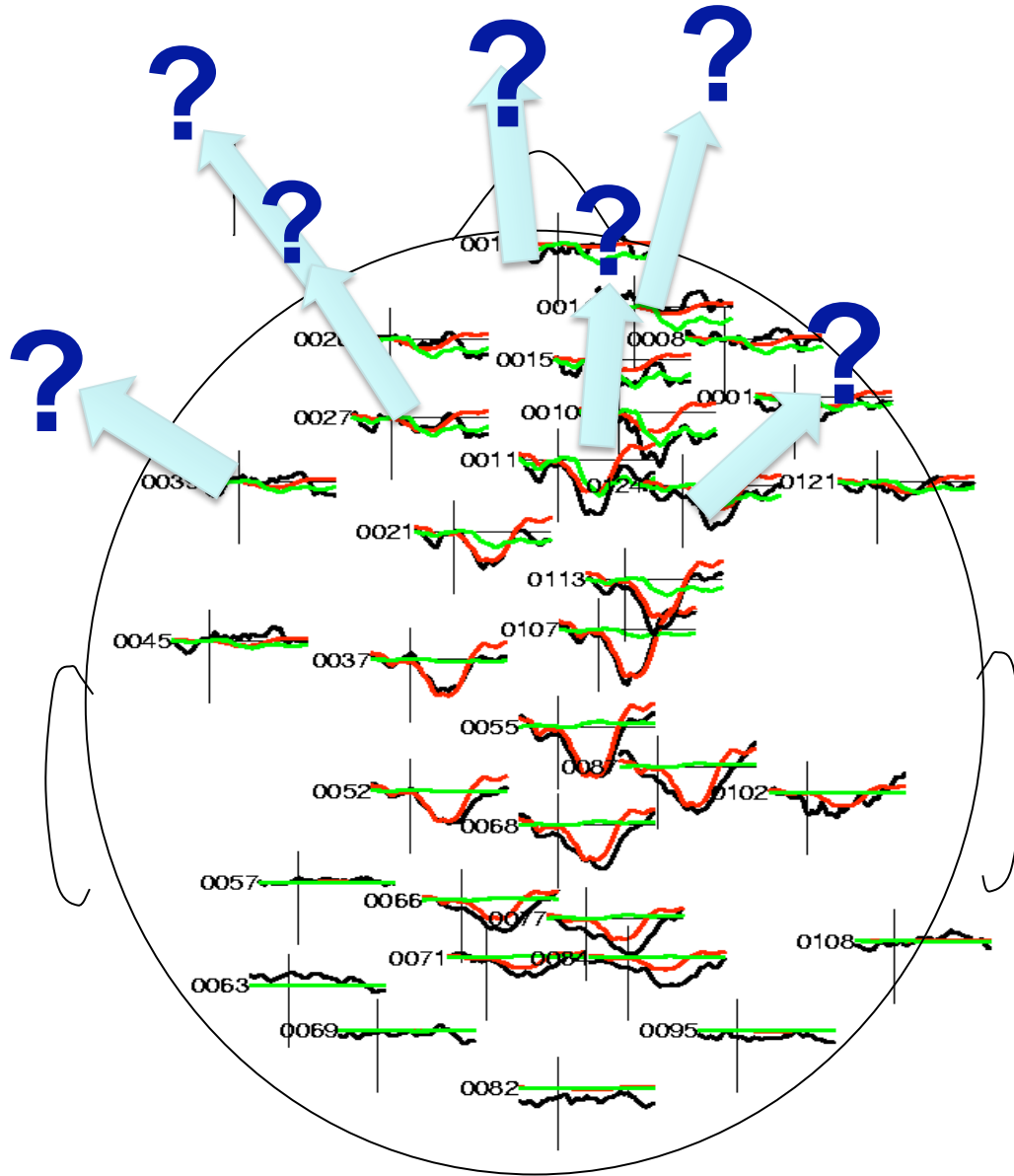
2-D Interpretation of Scalp EEG Signals?

# The Dome of the Sky

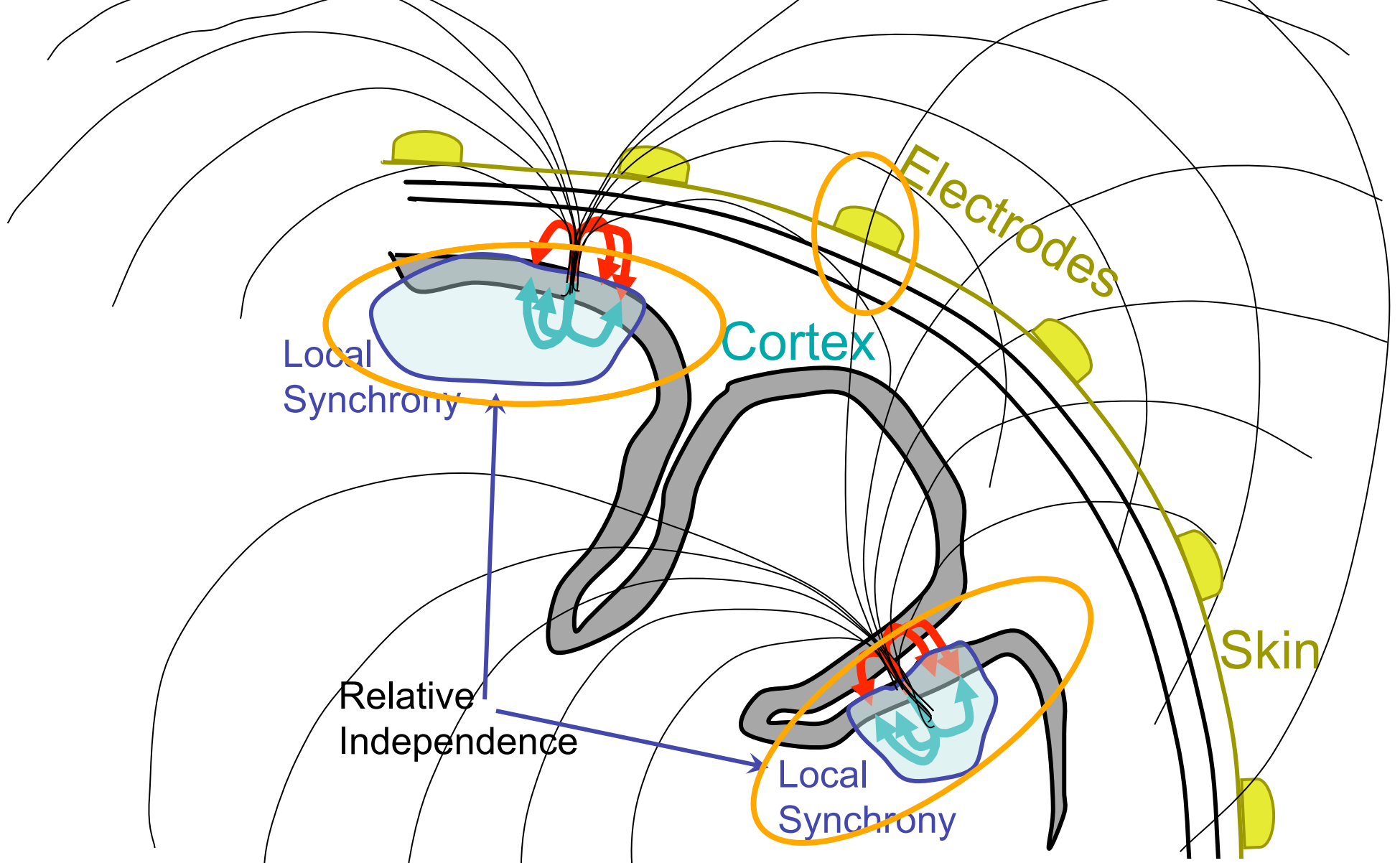


Very small point-spread of starlight ('twinkle') !

# Is EEG interpretation true **electrophrenology** ?

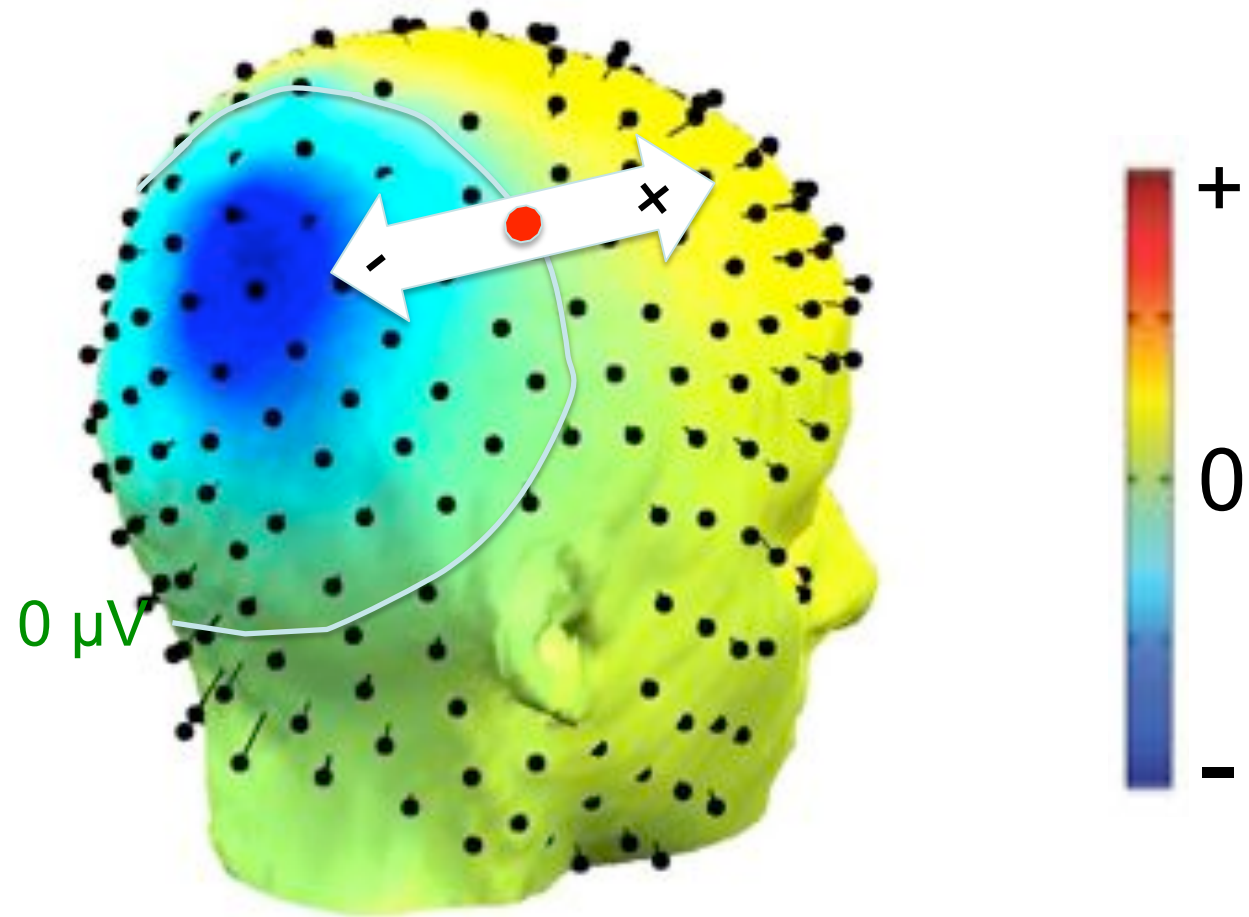


What is the 'point-spread' function for EEG?



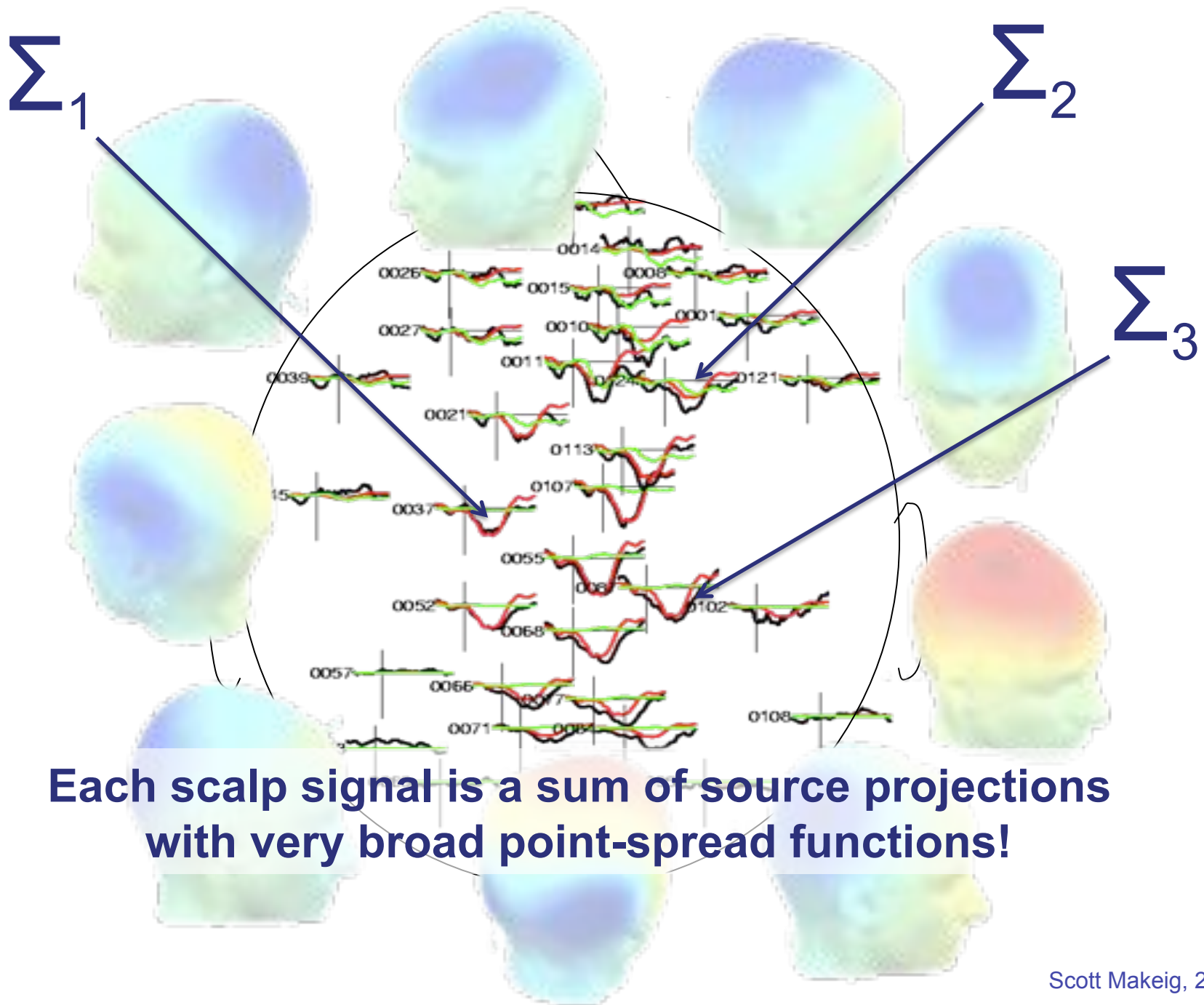
**SPATIAL SOURCE FILTERING!**

# The EEG point-spread function

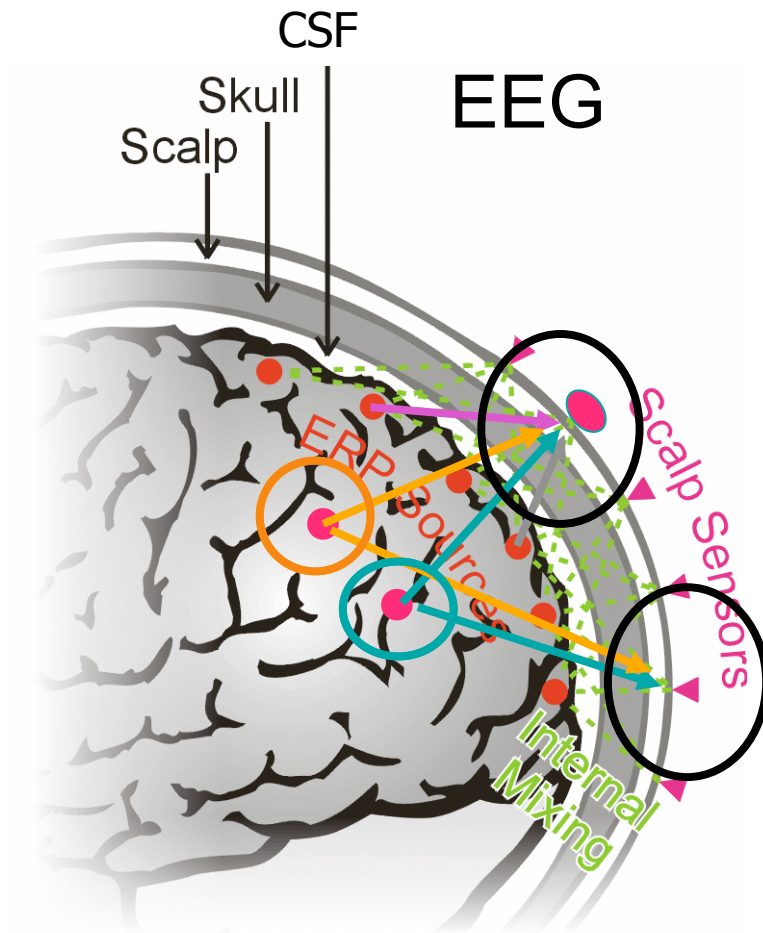


Each EEG source reaches  
nearly ALL the scalp channels!

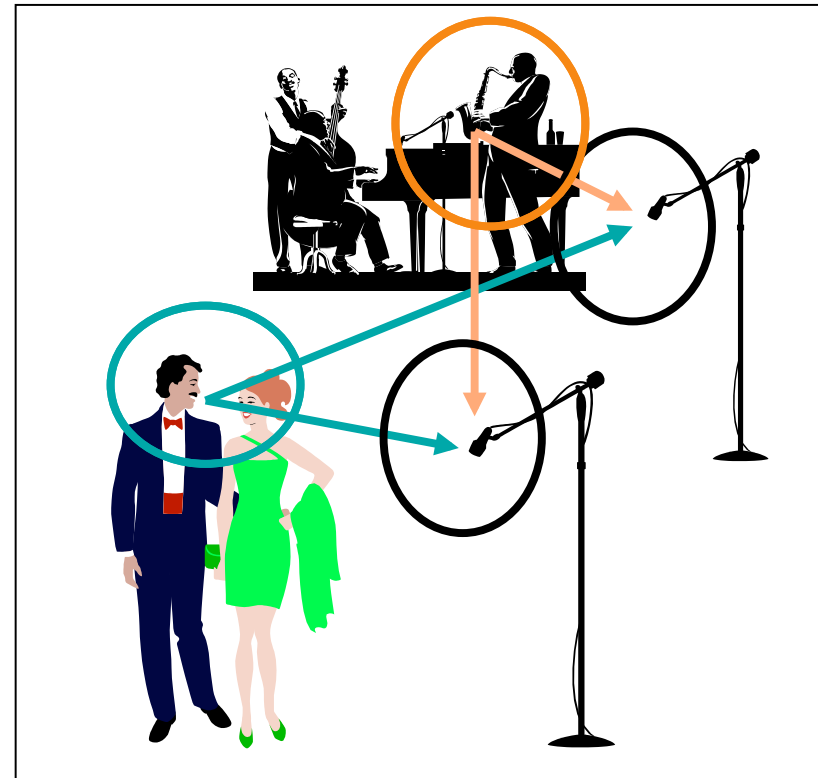




# Blind EEG Source Separation by ICA



## Cocktail Party



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## Independent Component Analysis of Electroencephalographic Data

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Computational Neurobiology Lab  
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San Diego, CA 92186-8400  
wskaggs@neuro.salk.edu



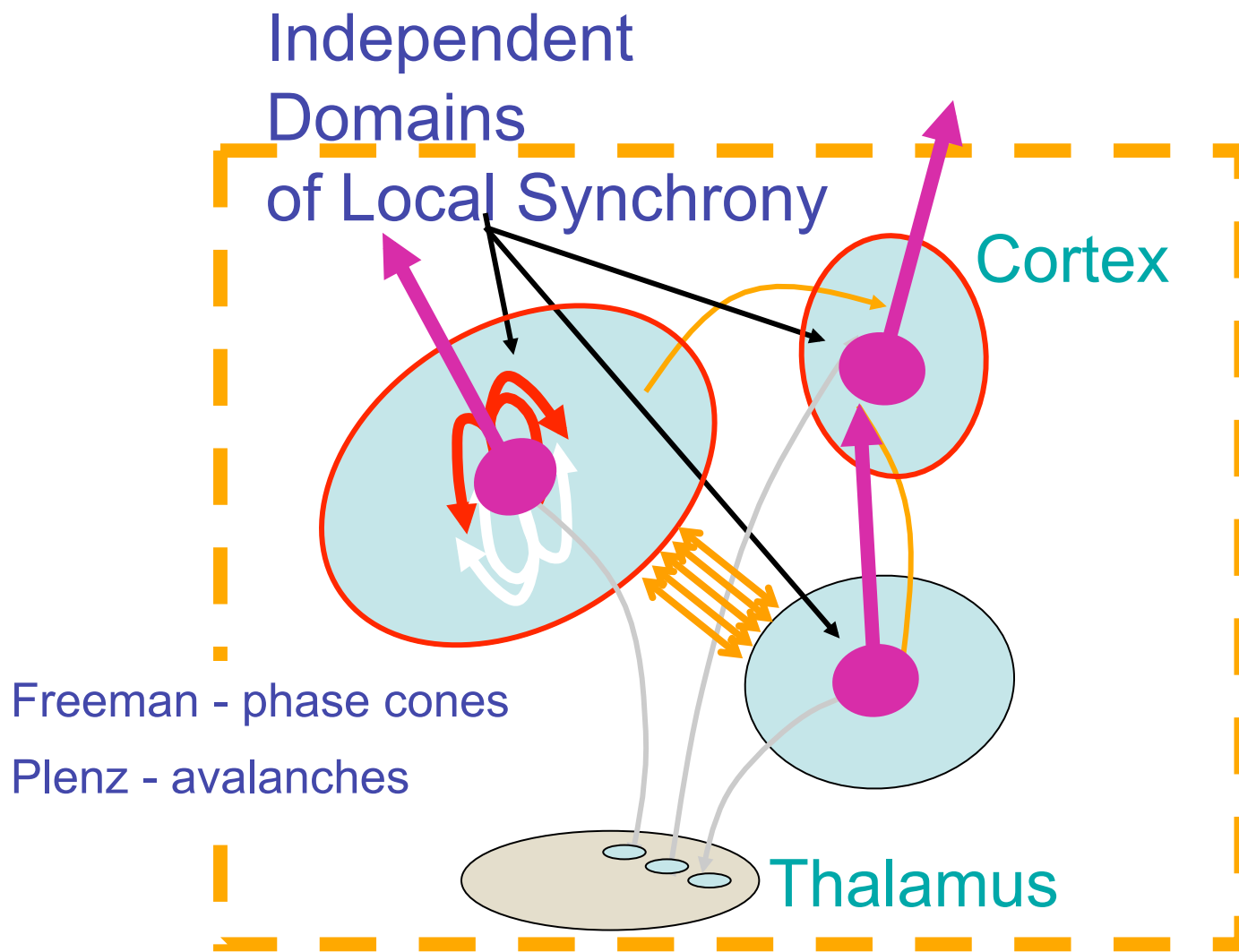
### Abstract

Features of the stimulus between the skull and scalp and their different sensitivities, electroencephalographic (EEG) data collected from any point on the human scalp includes activity generated within a large brain area. The spatial unmixing of EEG data by source localization does not resolve significant time delays, however, and

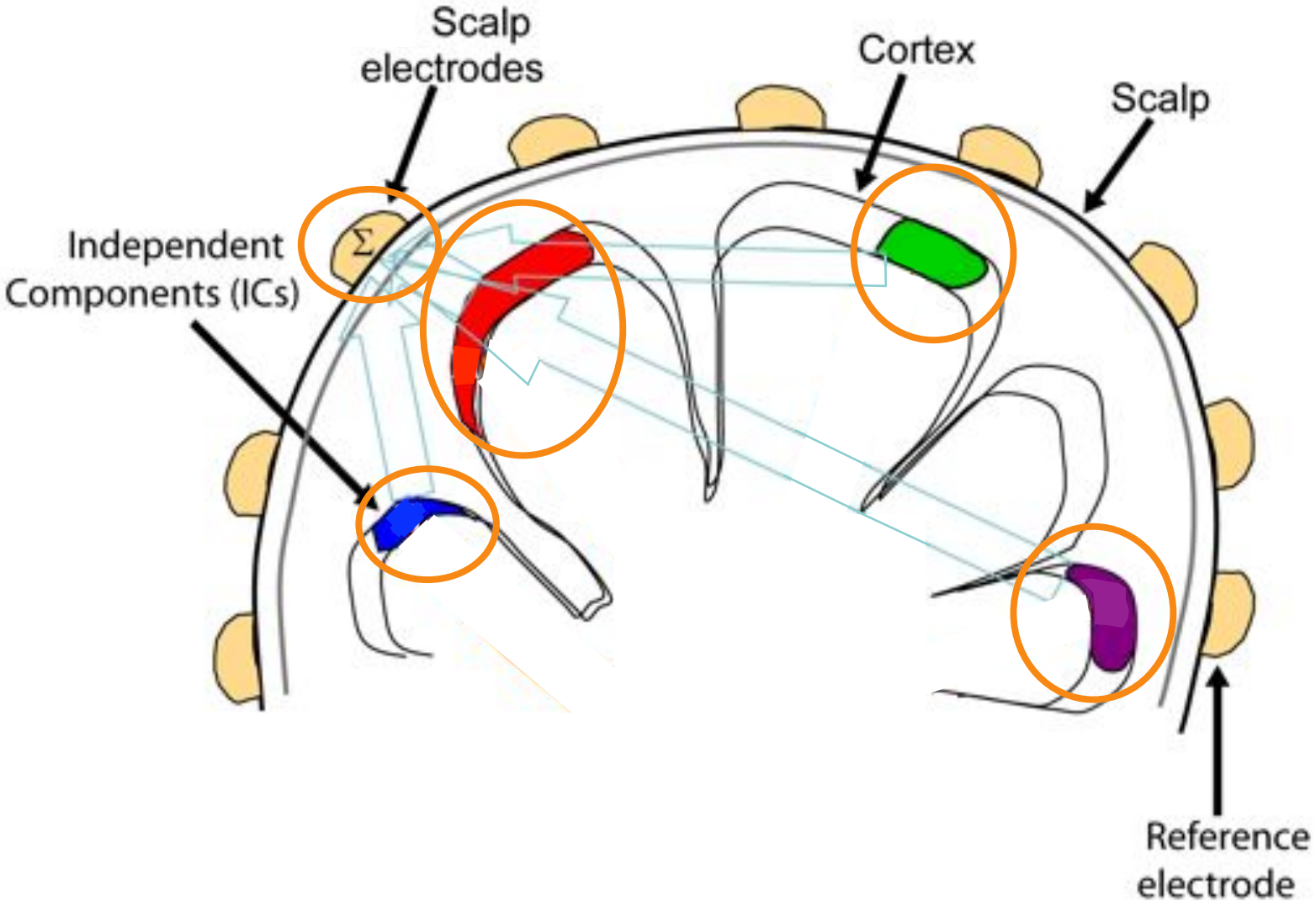
## Extended Infomax ICA

is applying the ICA algorithm to time and space-normalized (TSP) data collected during a sustained voluntary attention task show: (1) ICA is highly sensitive to different random noise, (2) ICA may be used to separate diverse collected EEG components (eye movements, eye movements) from other sources, (3) ICA is capable of isolating overlapping EEG phenomena, including alpha and theta bands, and quickly separates TSP components to separate ICA channels, (4) Nonstationarities in EEG and behavioral states can be tracked using ICA via changes in the amount of mutual correlation between ICA filtered output channels.

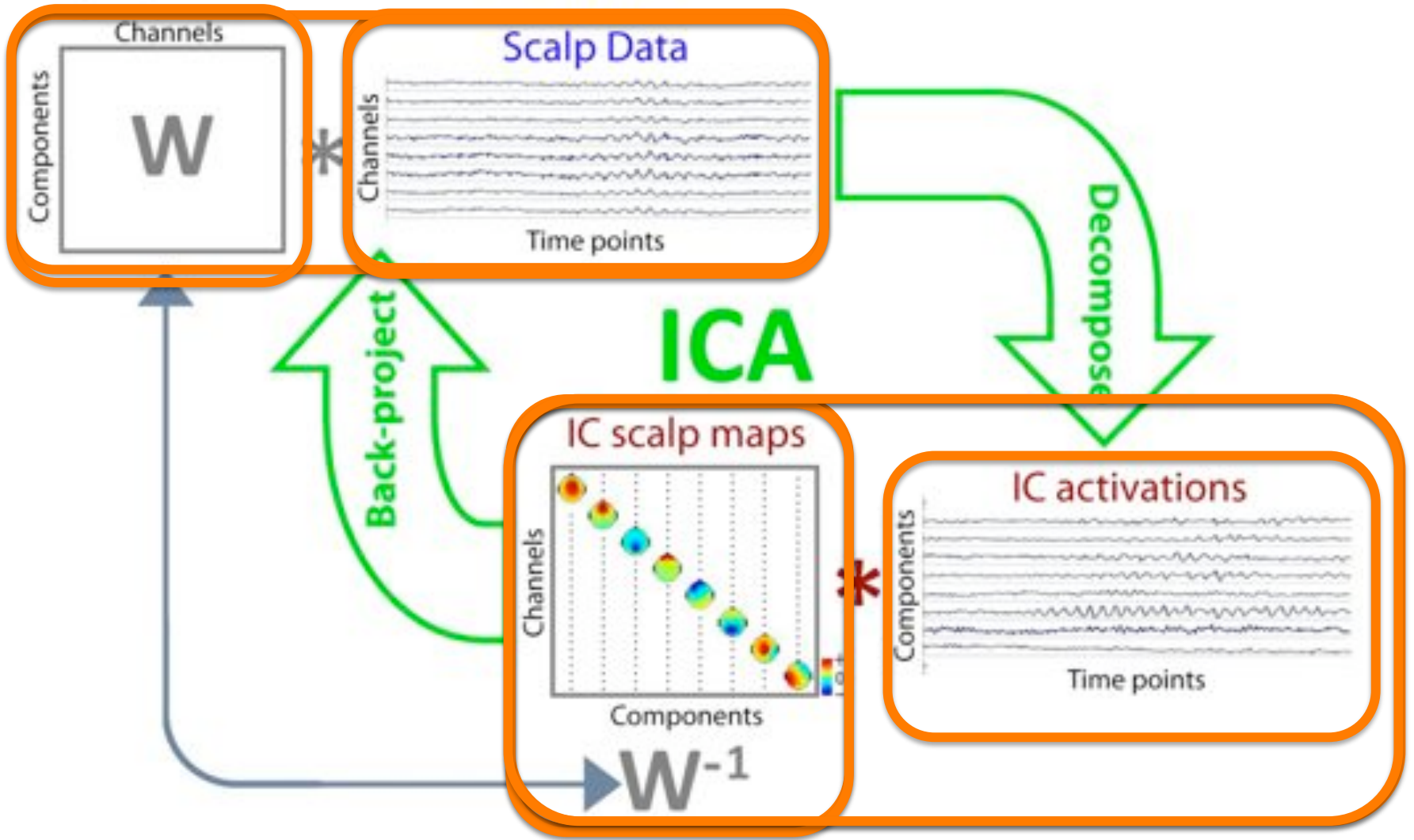
# Are EEG processes (nearly) independent?



# Independent Components







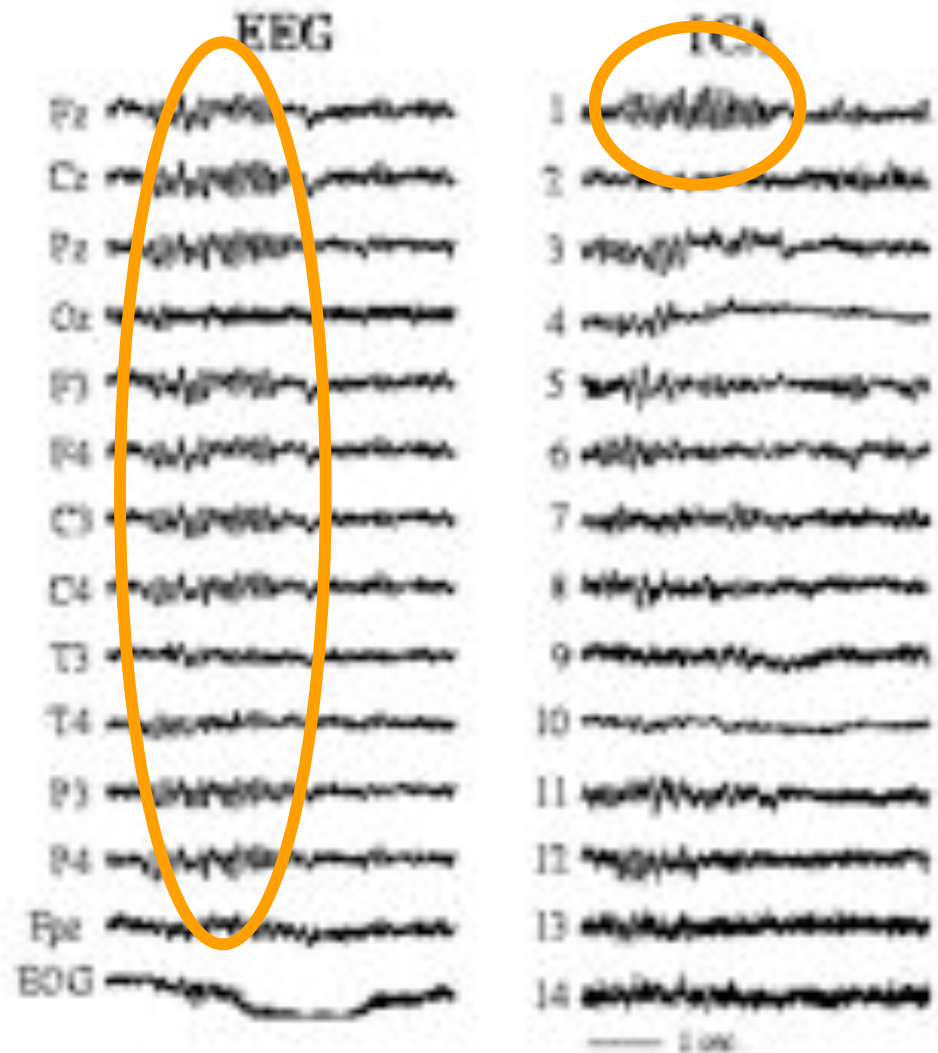
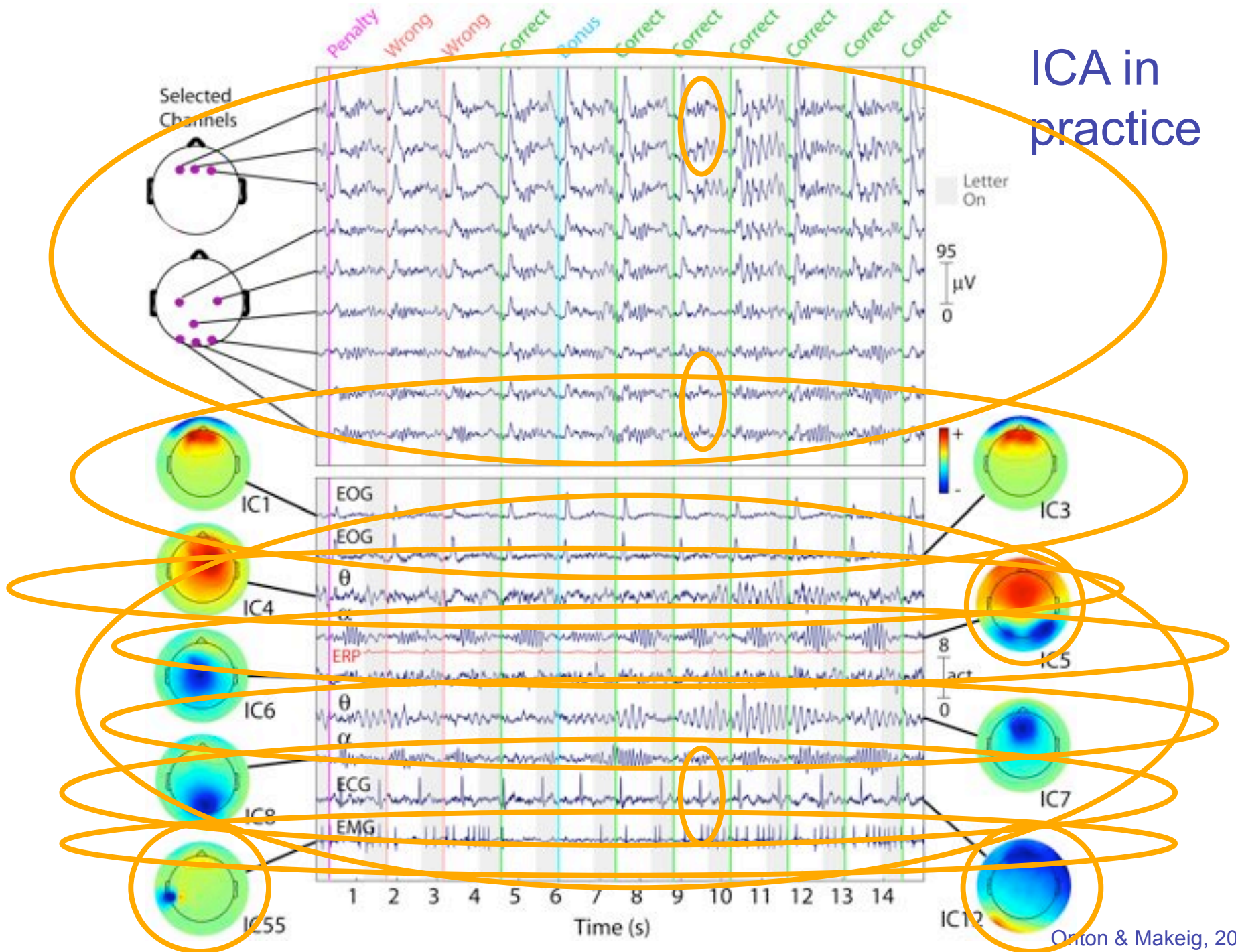
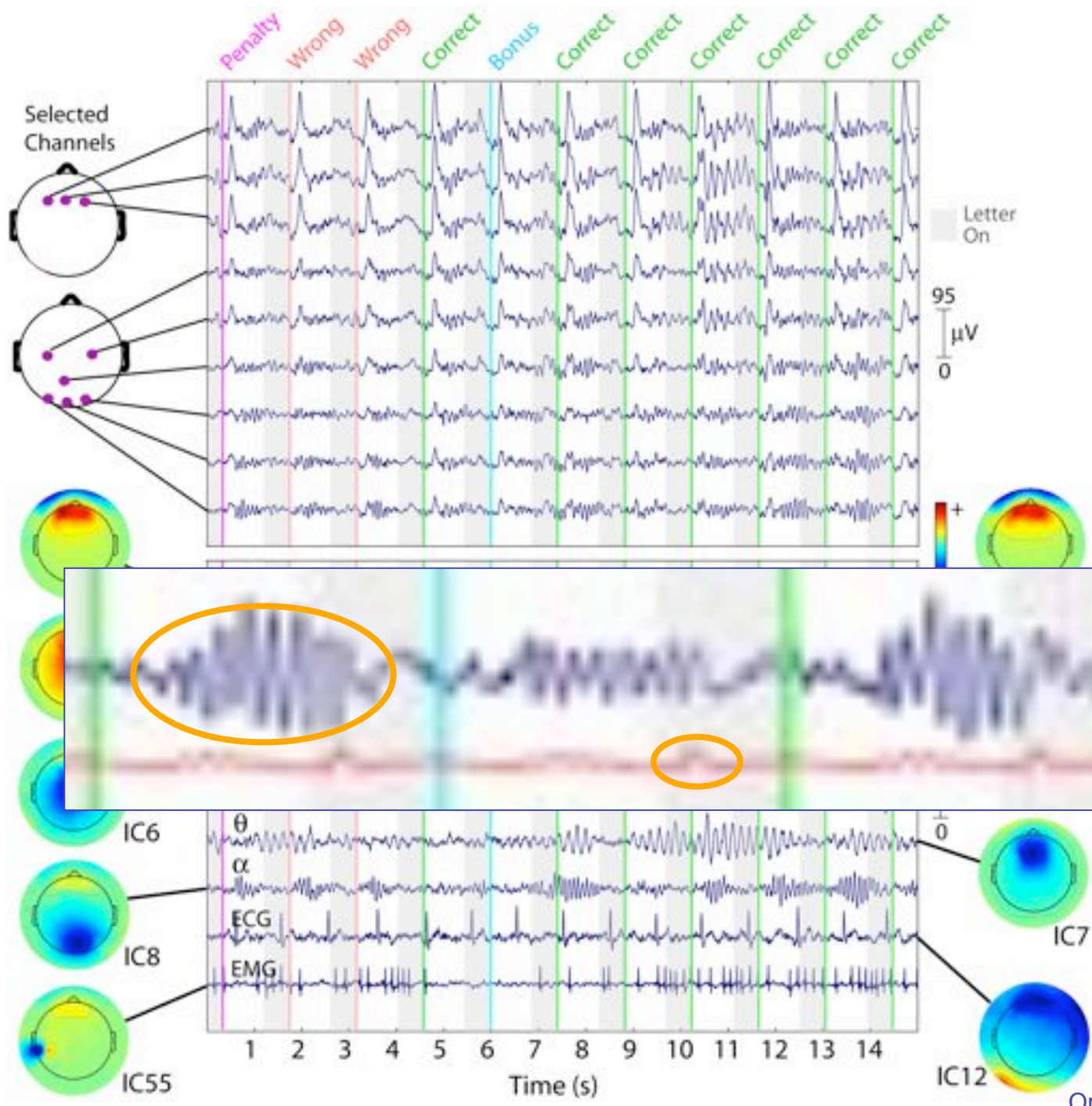


Figure 1. Left: 14 seconds of 14-channel EEG data. Right: an ICA transform of the same data, using weights trained on 63 minutes of similar data from the same subject.

# ICA in practice



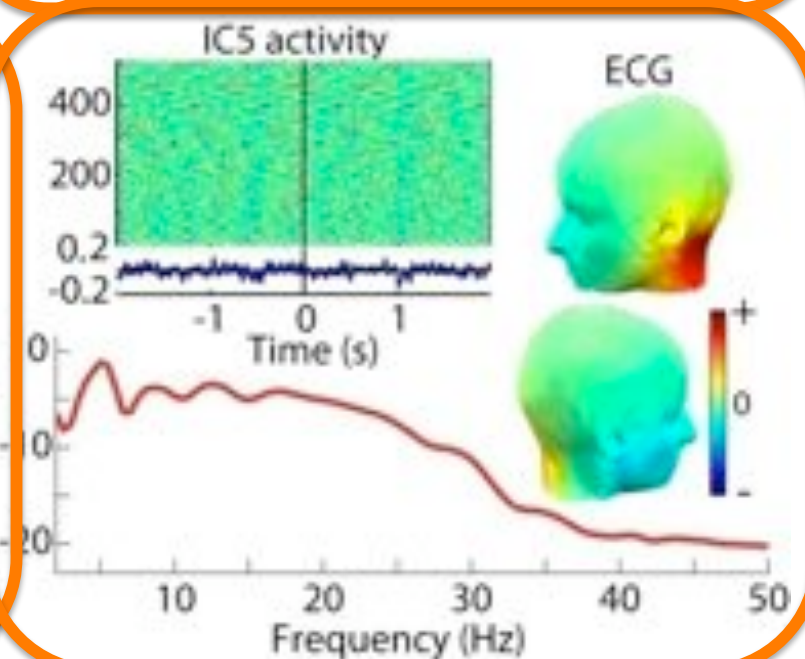
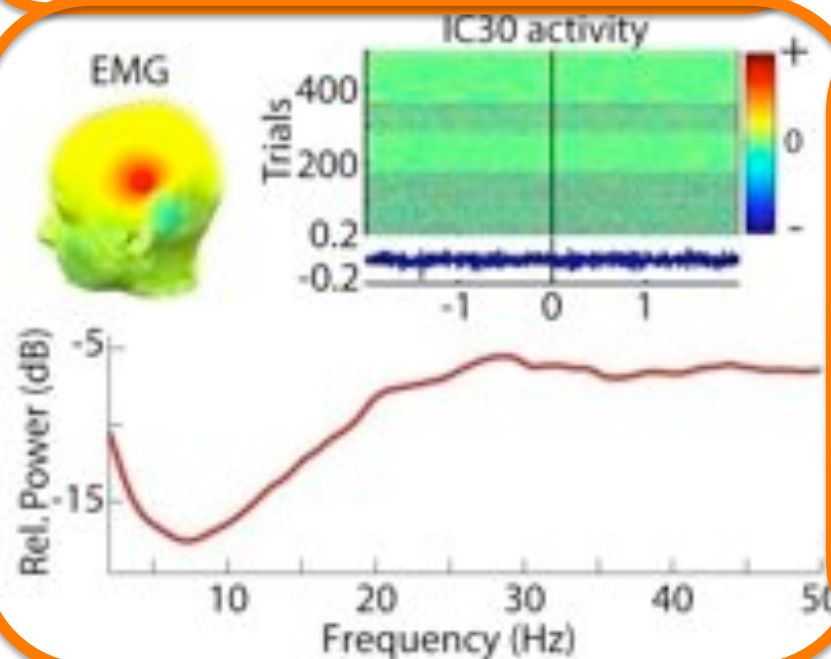
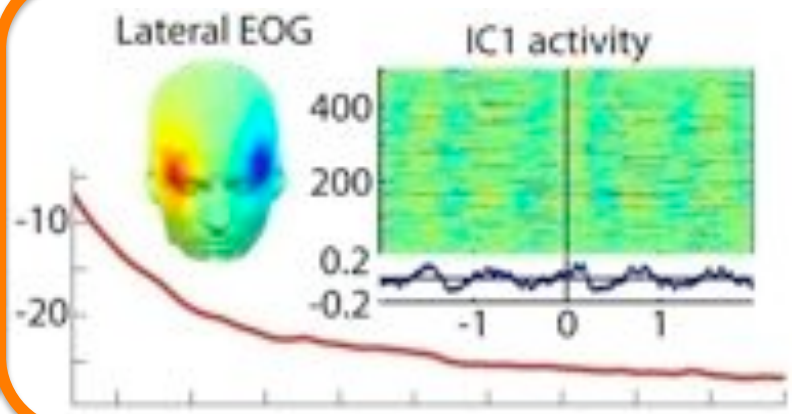
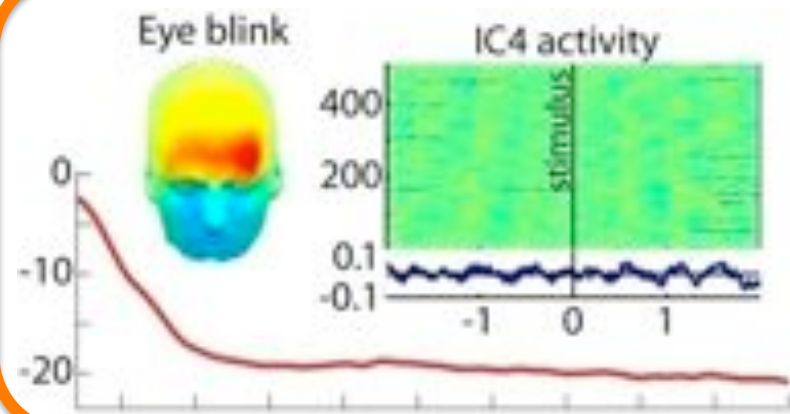




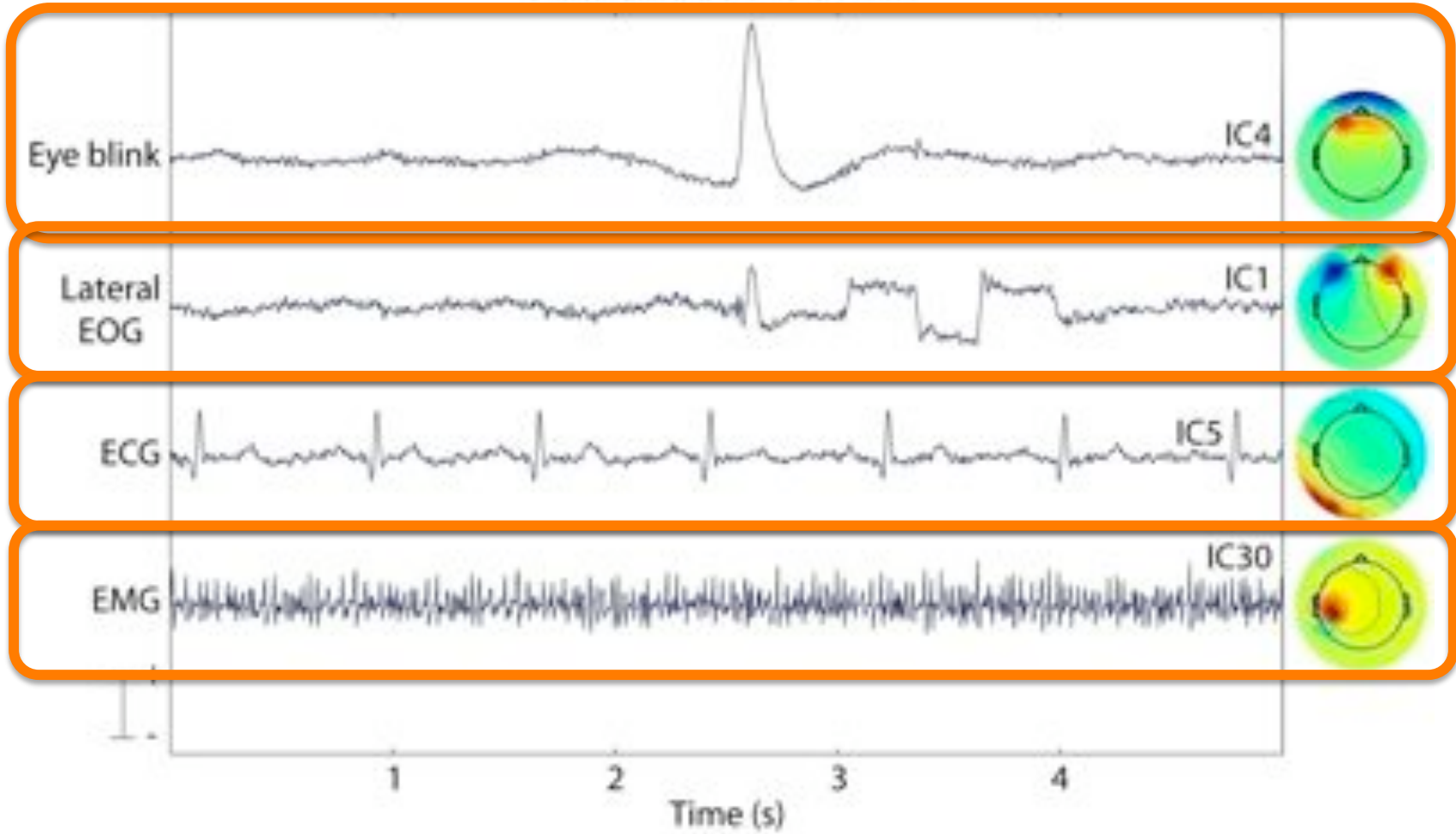
Onton, Makeig (2006)



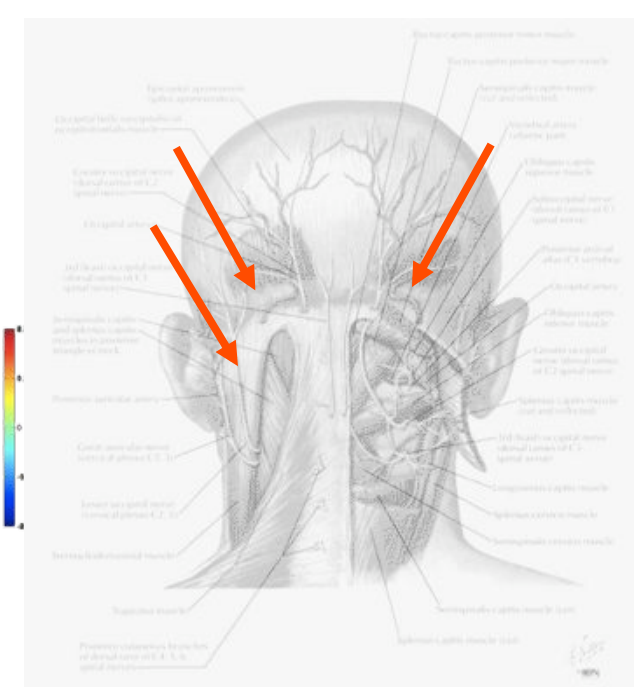
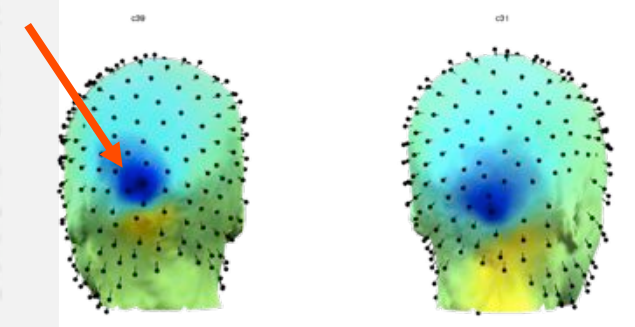
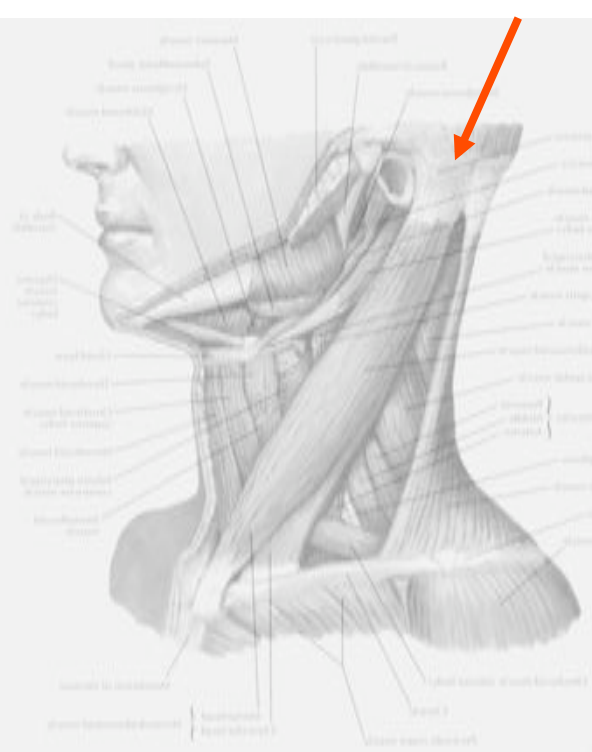
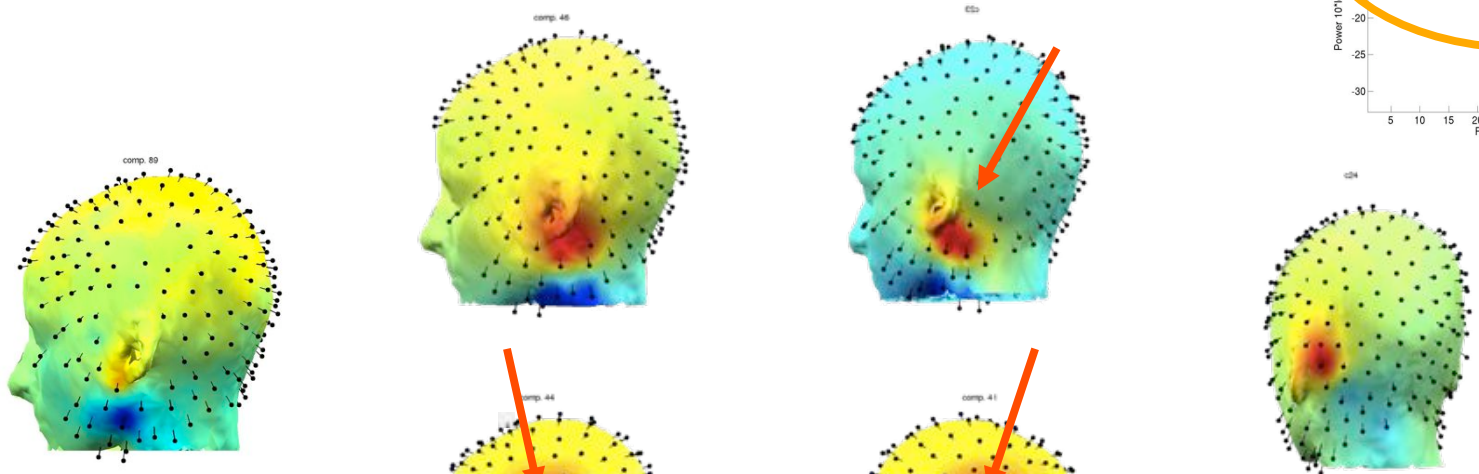
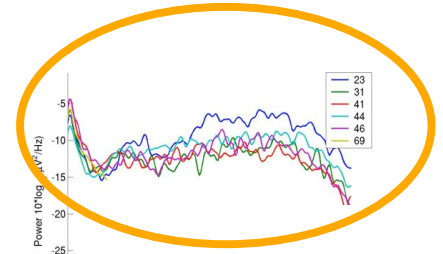
“ICA may be used to segregate obvious artificial EEG component (line and muscle noise, eye movements) from other sources.”



### IC activation time courses



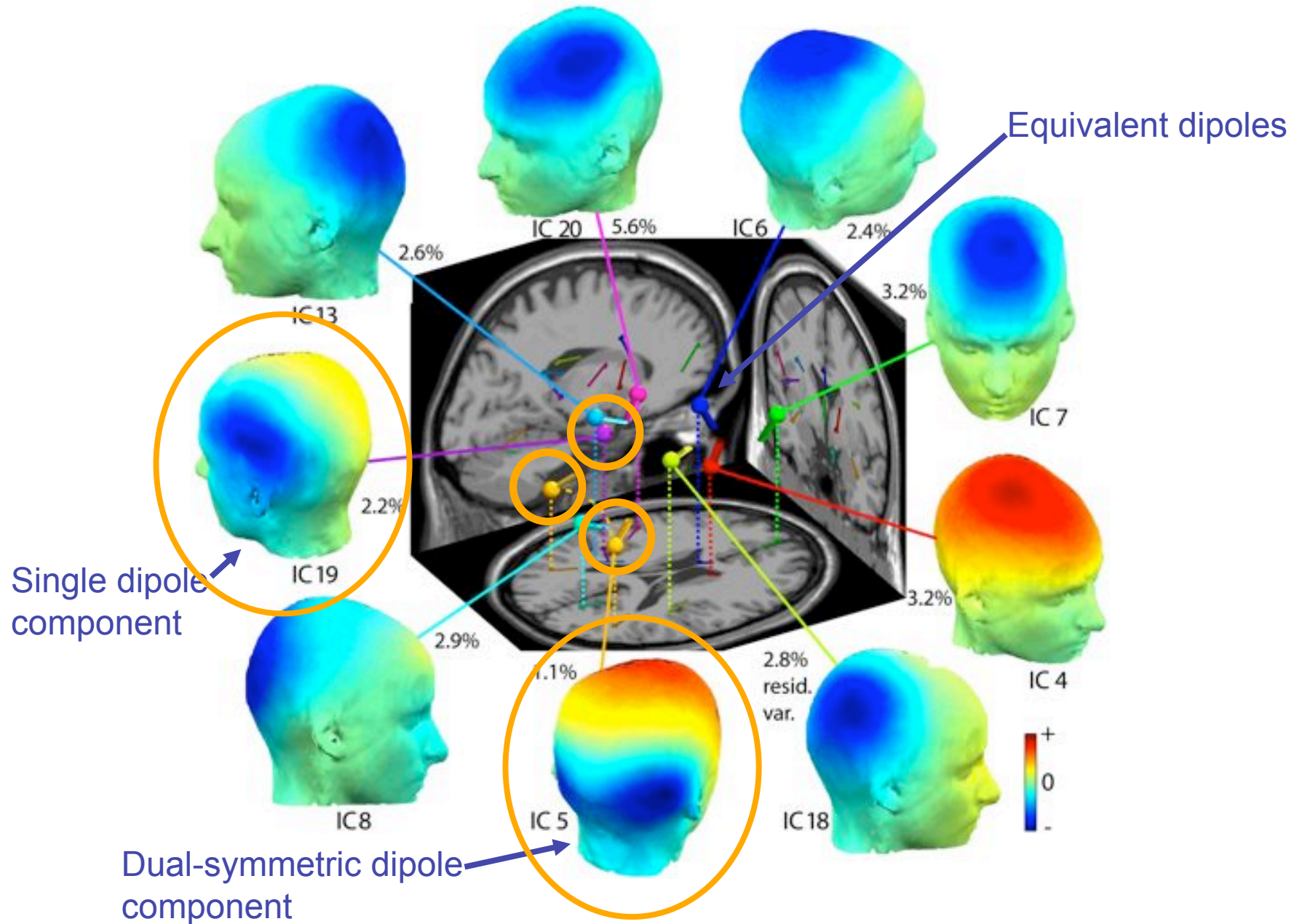
# Independent muscle components





“ICA is capable of isolating overlapping EEG phenomena including alpha and theta bursts and spatially separable ERP components, to separate [ICs].”

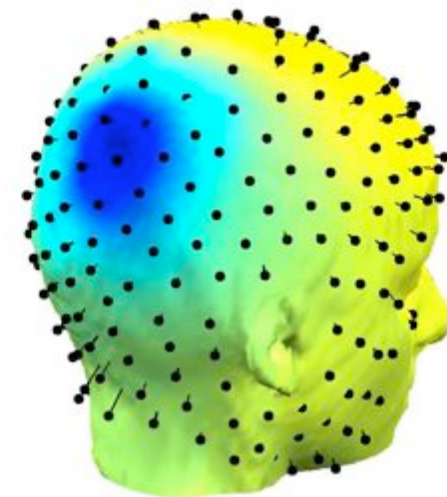
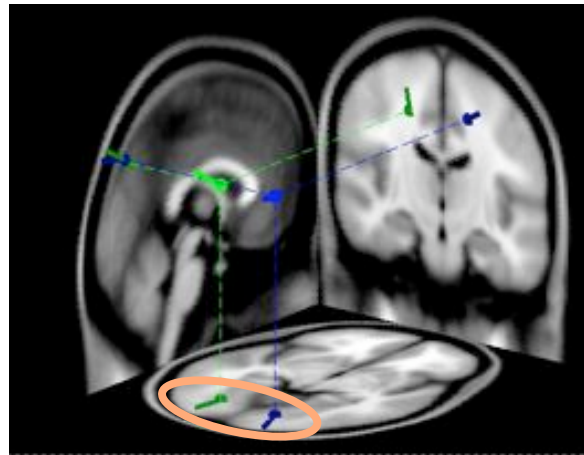
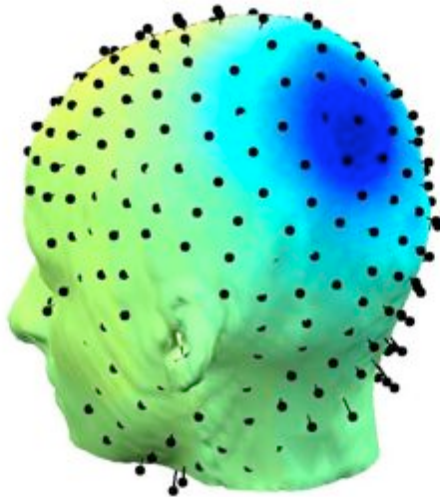
# Independent cortical components



# Single Session - Two Maximally Independent Central Alpha Processes

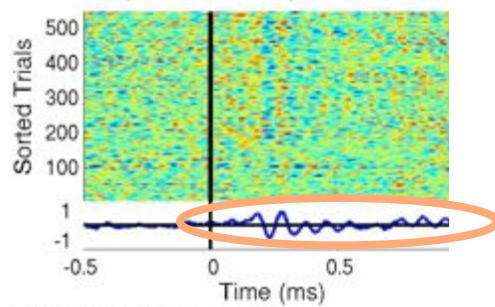
IC9

IC11

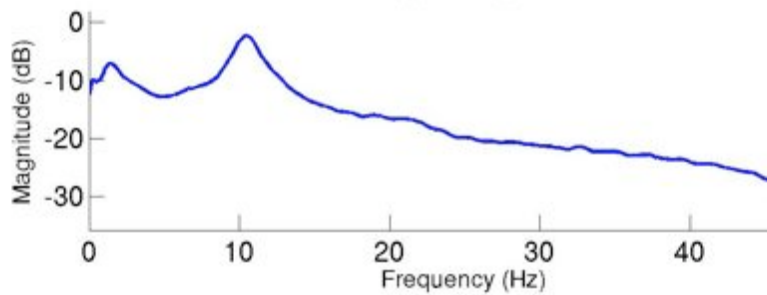


Component 9 map

Component 9 activity (global offset 0.02)

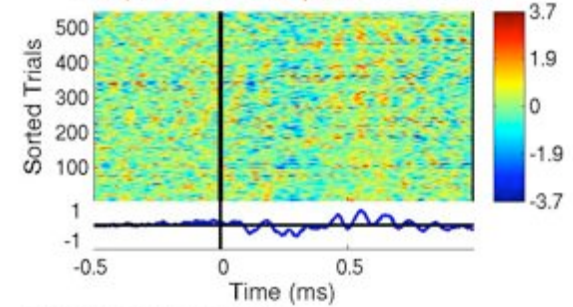


Activity power spectrum

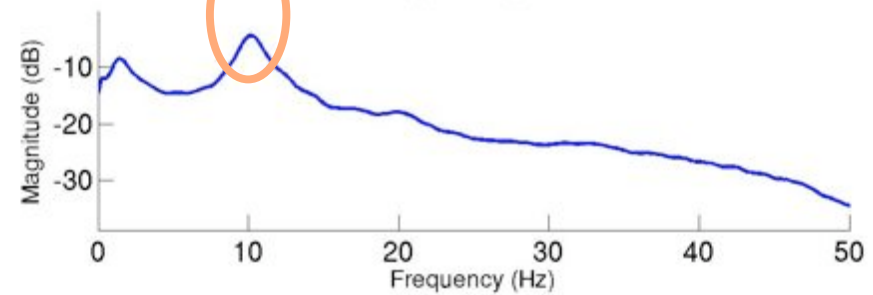


Component 11 map

Component 11 activity (global offset -0.038)



Activity power spectrum

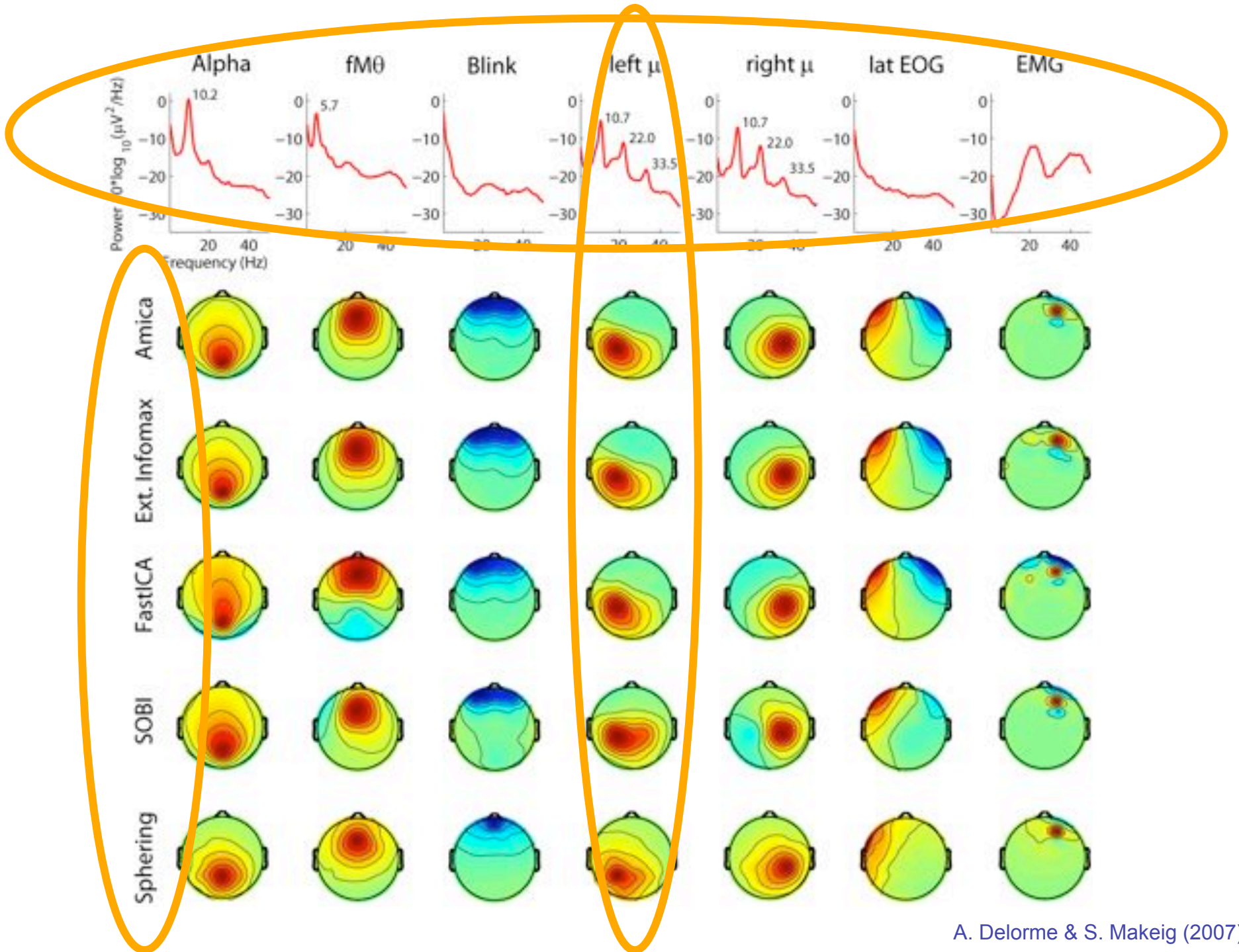


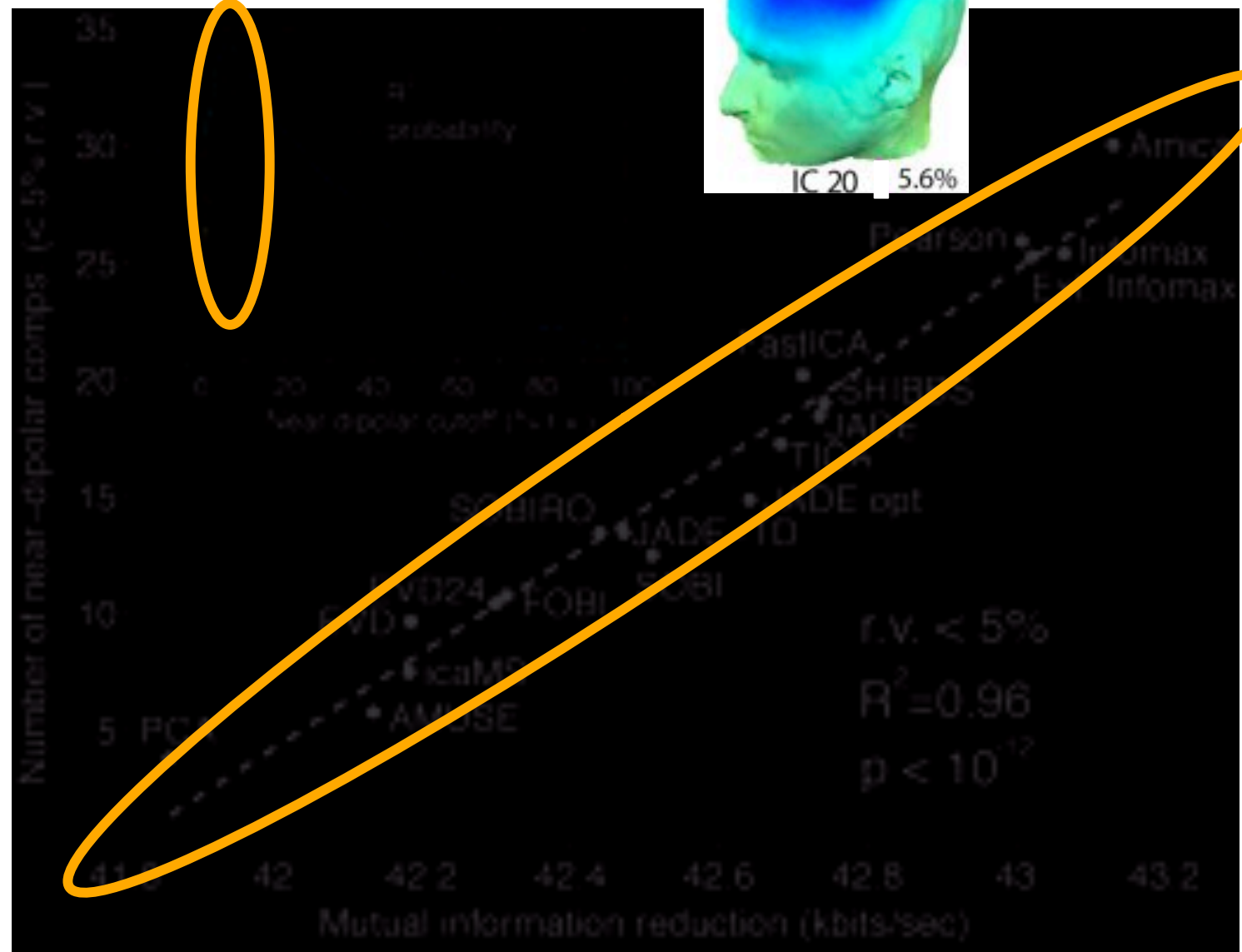
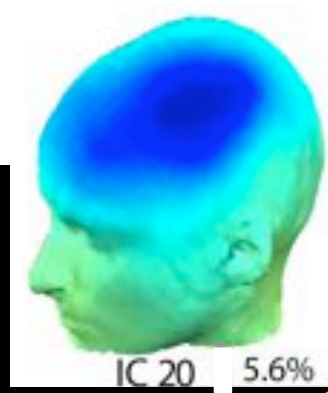
compprop()

“ICA training is insensitive to  
different random seeds,”  
... and can separate out  
independent components of  
data with hundreds of  
channels.



Moreover, ICA separates out  
'dipolar' components  
that may be relatively stable  
across algorithms.

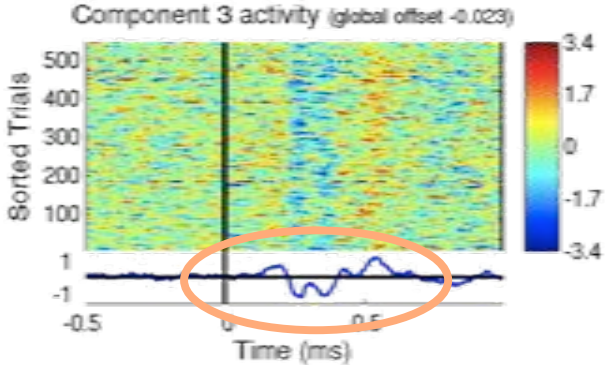
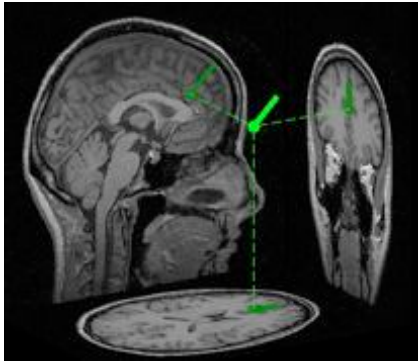




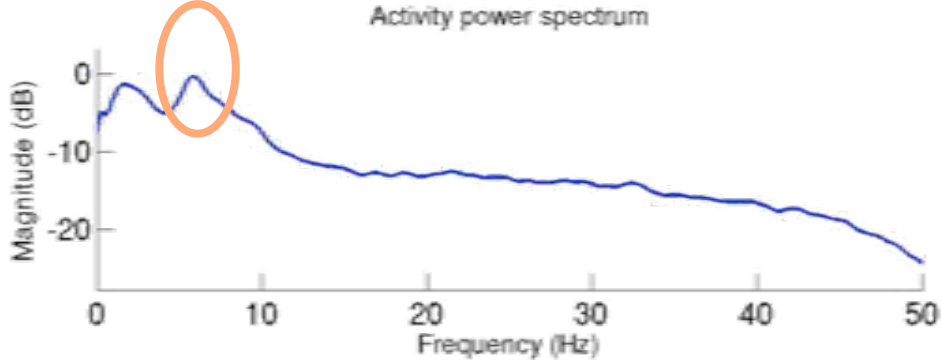
Decompositions that  
find components that are **more independent**  
→ find **more** 'dipolar' components!



# Frontal Midline Theta Process



Activity power spectrum



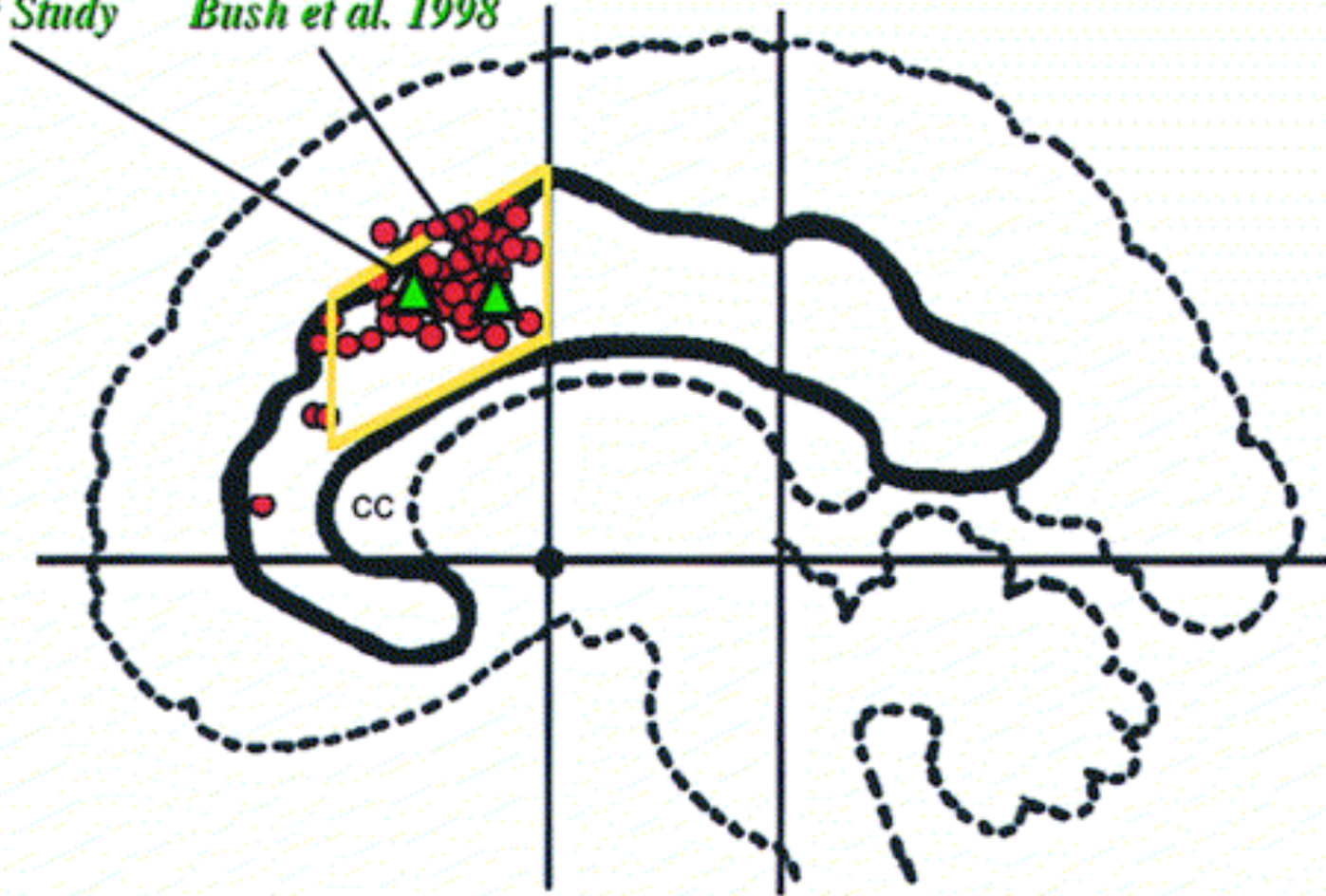
IC3



# Anterior Cingulate Cognitive Division

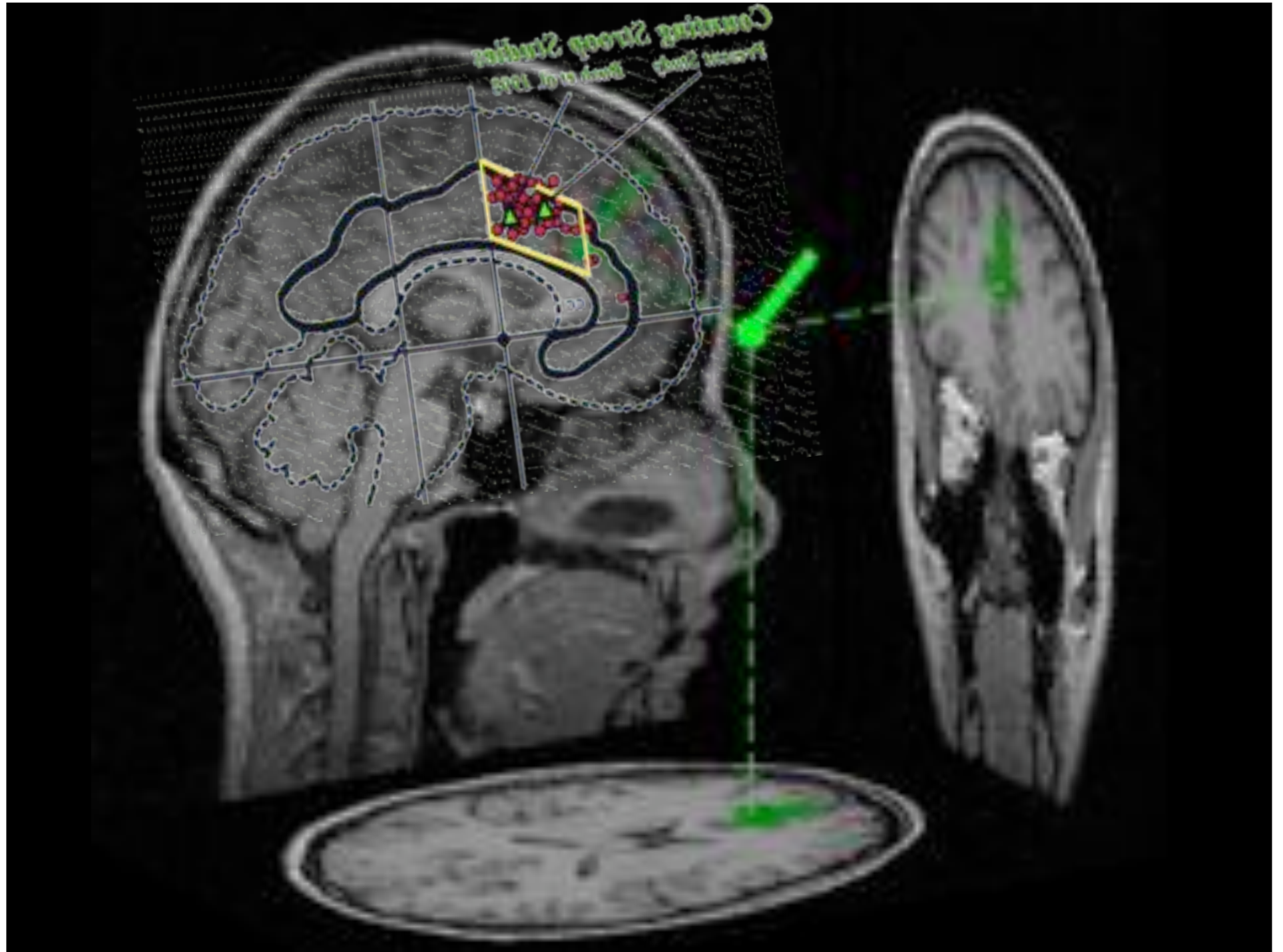
## Counting Stroop Studies

*Present Study*     *Bush et al. 1998*



Bush et al., 1999

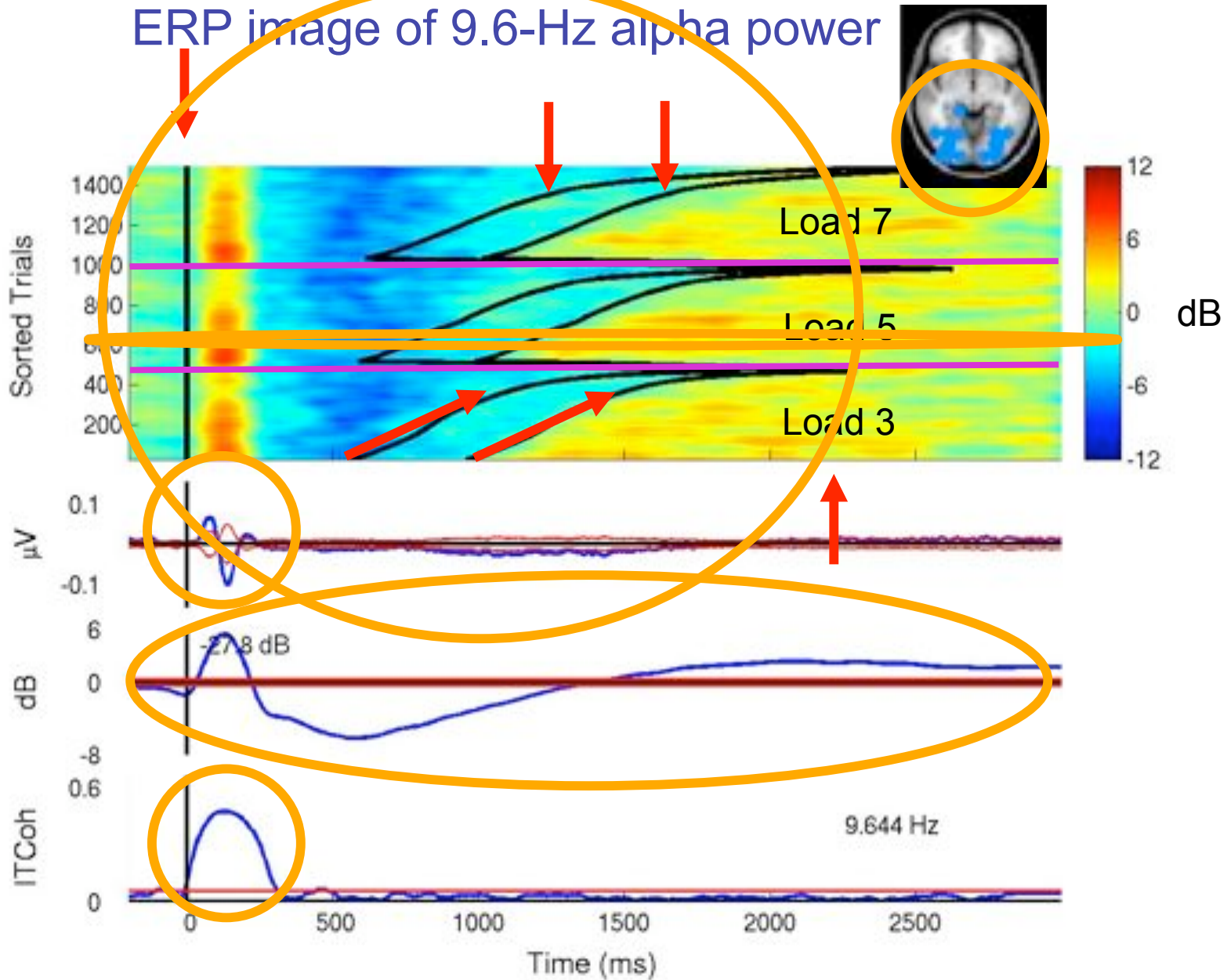






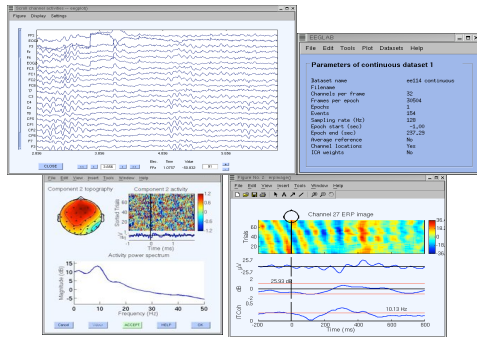
Independent components of EEG data tend  
to be **functionally independent.**

# ERP image of 9.6-Hz alpha power



erpimage()

Onton, Delorme & Makeig, 2005.



# Beginning...