

Mining Cognitive Brain Dynamics I



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14th EEGLAB Workshop @ Palma, Mallorca

September, 2011

Functional Brain Imaging

Some human brain imaging milestones

1926 ~1st human EEG recording

EEG era

1938 1st EEG spectral analysis

1962 ~1st computer ERP averaging (CAT)

ERP era

1979 1st event-related desynchronization

1993 1st fMRI BOLD recordings

fMRI era

1993 1st broadband ERSP

1995 1st multisource EEG filtering by ICA

2009 ~1st commercial dry electrode EEG toys

fEEG / BMI / MoBI era ...

FIGURE 1-2.—Sample of the first EEG tracing taken at the Bradley Hospital, E. Providence, Rhode Island, by H. Jasper and L. Carmichael. Subject: Carl Pfaffmann. Date: July 9, 1934. Record, which shows prominent alpha rhythm of about 11.5 per second, was made with a Westinghouse, galvanometer-type, mirror oscillograph. Time line above: 25 Hz.

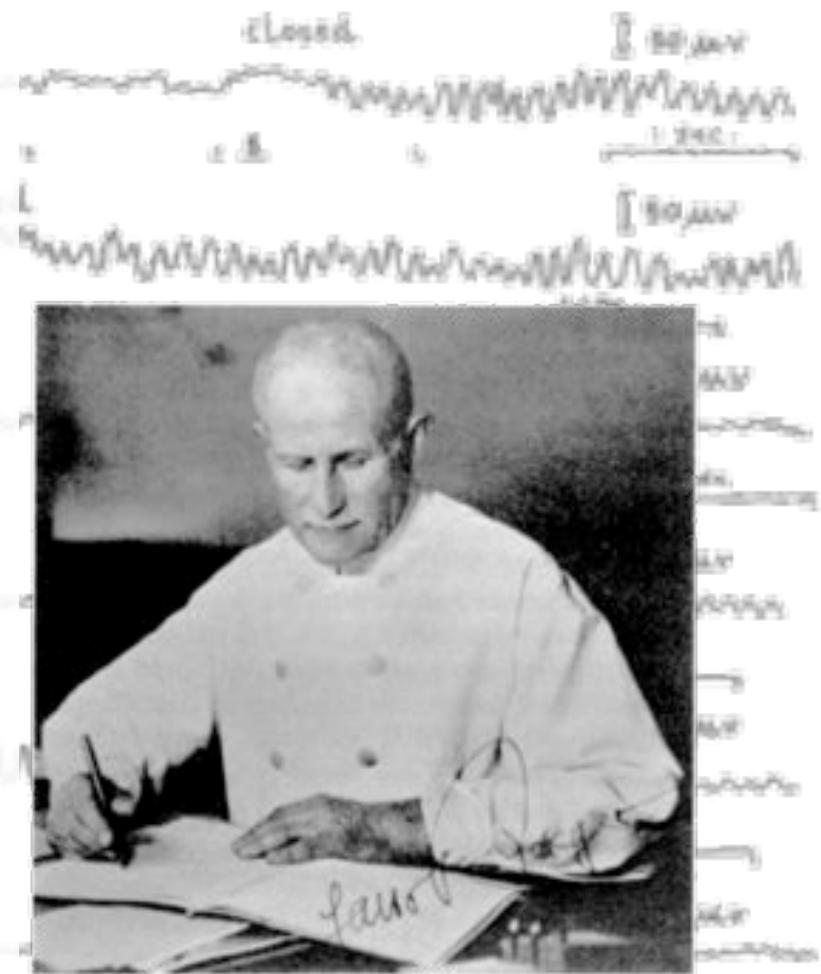
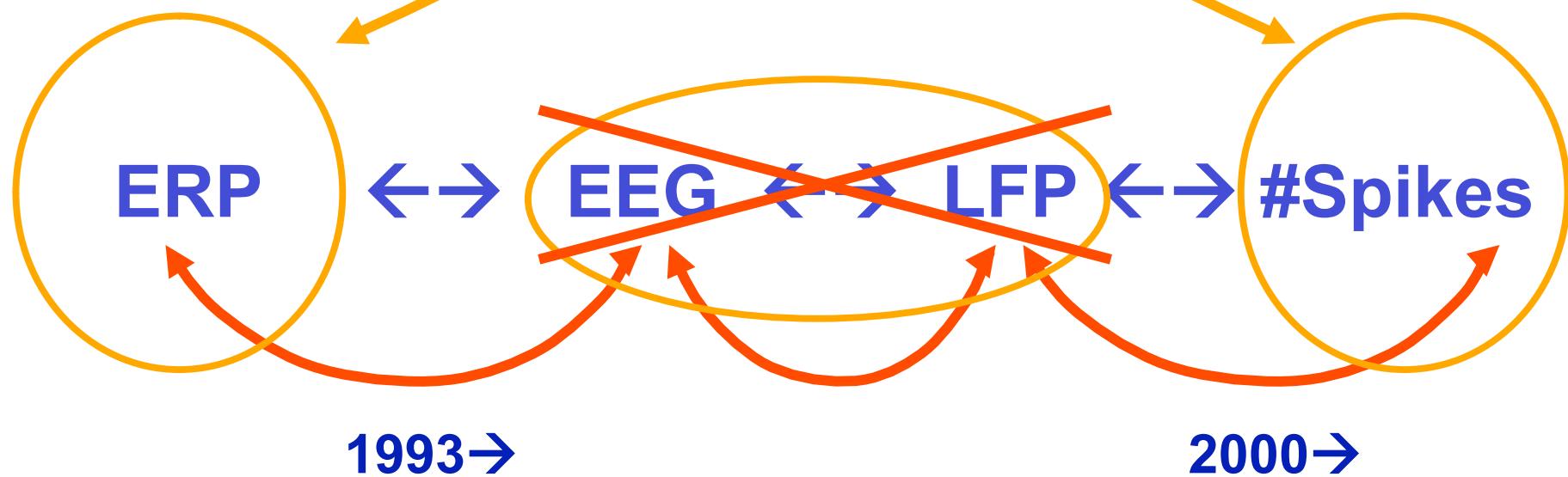


FIGURE 1-1.—Professor Hans Berger (1873–1941), neuro-psychiatrist, University of Jena, Jena, Germany, first to discover and describe in 1929 a unique kind of electrical activity recorded from the brain of man, which he named the electroencephalogram (Elektrenkephalogramm).

S. Makeig 2010

Brain Electrophysiology ?

2011 →



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 – 1st EEGLAB (sccn.ucsd.edu)**
- 2004 - NIH support – (Delorme & Makeig, 2004) reference paper (now 1300 gSrefs)
- 2004 - 1st EEGLAB workshop (UCSD, La Jolla, California)
- **2004 - 1st EEGLAB plug-ins**
- 2005 – Workshops in Porto (Portugal) and Lisbon (SPR)
- 2006 – Workshop in Singapore
- **2006 - 1st 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 – New toolboxes: SIFT, BCILAB, MPT**
- 2010 – Workshops in Jyvaskyla Finland, NCTU, Taiwan, Portland Oregon, and UCSD
- **2011 - HeadIT resource, ERICA (Experimental Real-time Interactive Control & Analysis)**
- 2011 – Workshops in Aspet, France and Palma, Mallorca
- **2011 – EEGLAB Chat to be introduced ...**

EEGLAB downloads for 20/06/2007

Total count is 34

Username	Email	Comments
Russia	@mail.ru	ecg, erp, bci
Company	@nexstim.com	EEG developer
Indonesia	@tf.jib.ac.id	Brain Computer Interface
Finland	@psyka.jyu.fi	
Australia La Jolla	@newcastle.edu.au @gmail.com	Auditory Psychophysics Psychopathology EEGlab is great!
Chinca	@126.com	hi!
?	@yal.com	EEG in IBS patients
US Gov	@pnl.gov	
US EDU	@bethelks.edu	EEG and ERP responses to music stimuli
US EDU	@wlu.edu	Neuroimaging olfaction ERP
Switzerland	@student.ethz.ch	
Sweden	@nuro.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 in all
- >3,500 on the 'eeglablist' discussion list
- 30+ EEGLAB plug-ins available

EEGLAB Workshops

2009 Participants:

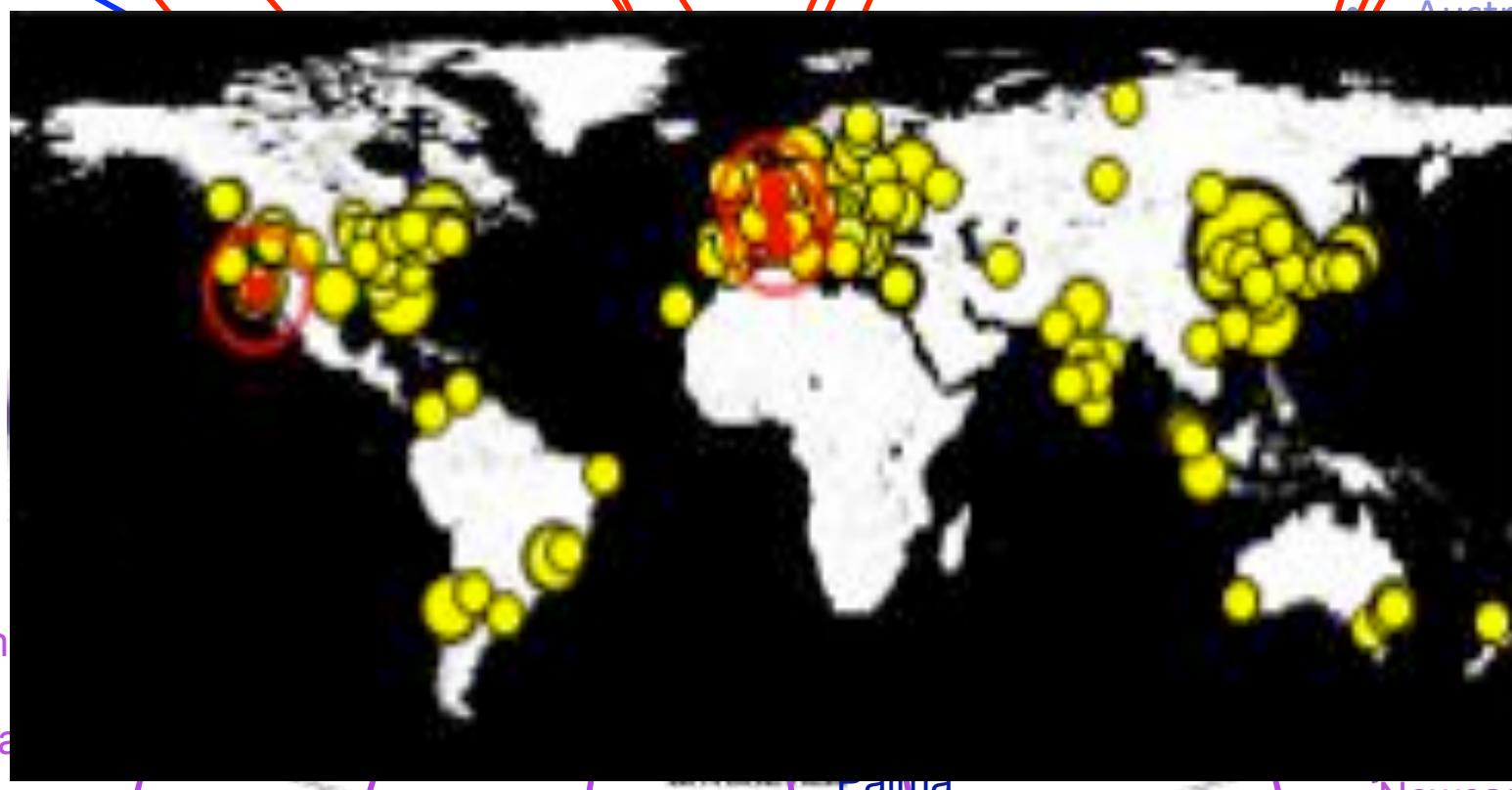
- Canada
- USA

Montreal

- Norway
- Ireland
- England

- Germany
- Austria
- Italy

- Japan
- Taiwan
- S. Korea
- Australia



Bloomin

Portla

La Jolla

Santiago

Porto

Aspet
Palma

Jyväskylä

Newcastle
Singapore

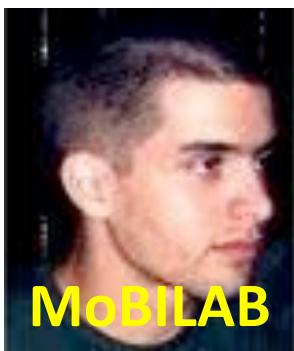
S. Makeig 2011



Arnaud Delorme



Jason Palmer



Alejandro Ojeda
S. Makeig (2011)



Julie Onton



Tony Bell



Christian Kothe



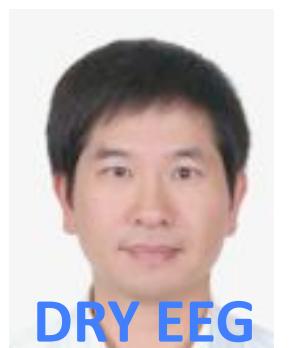
Tim Mullen



Zeynep
Akalin Acar



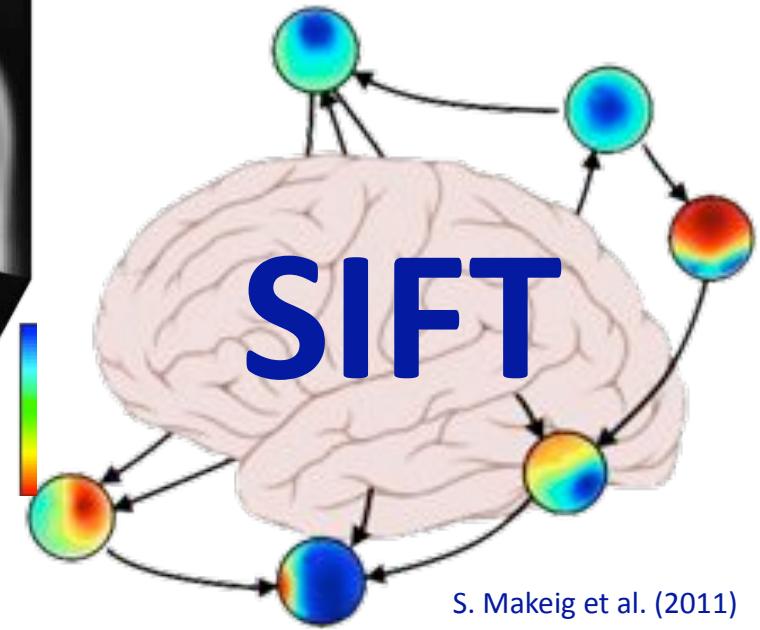
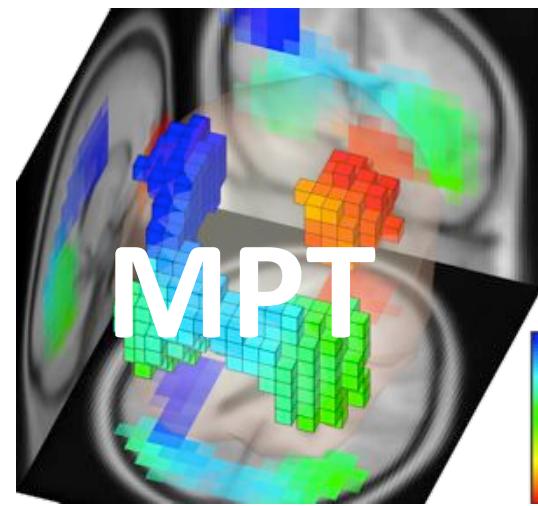
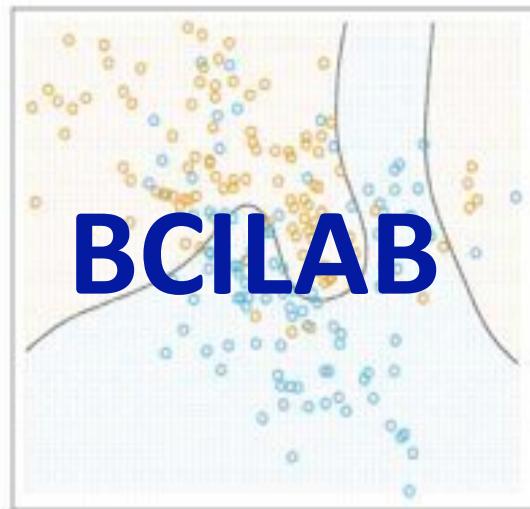
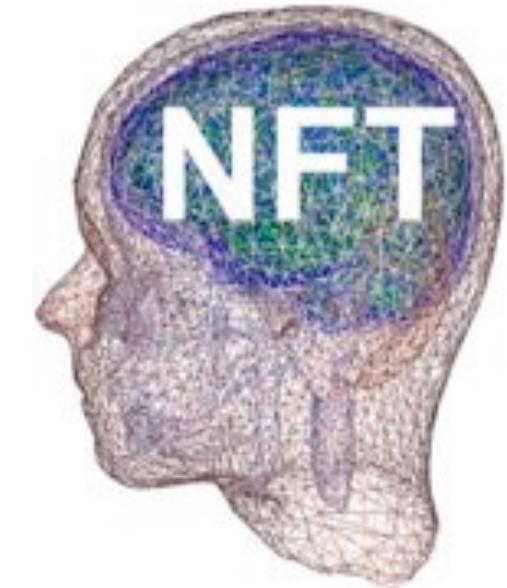
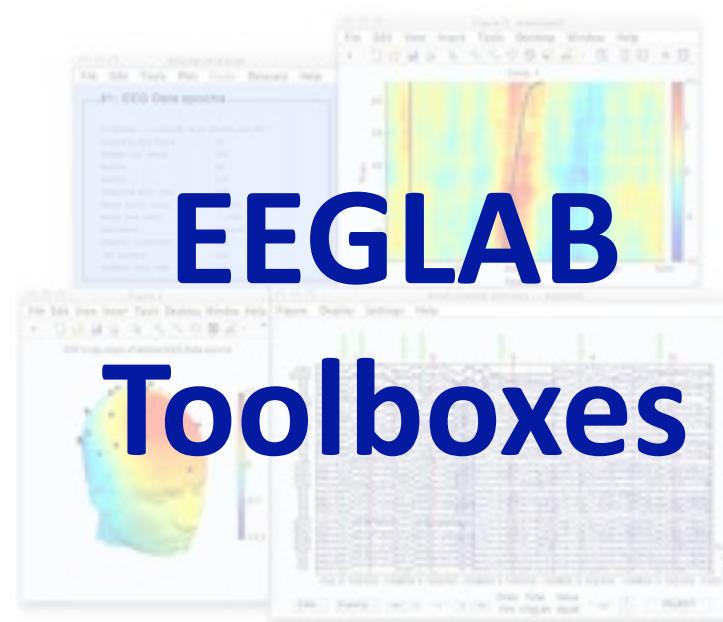
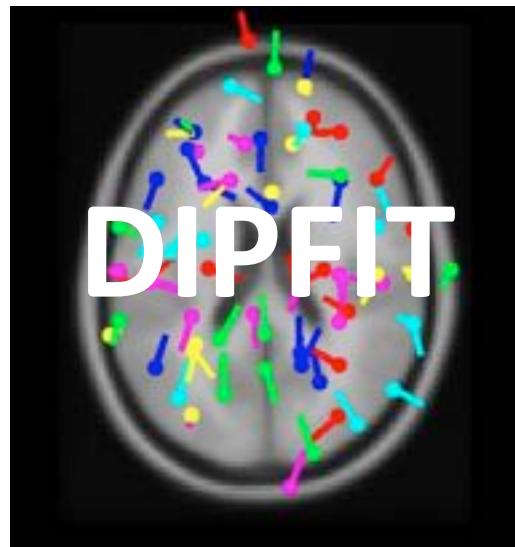
David Groppe



DRY EEG
Tzzy-Ping Jung



MPT
Nima Bigdely
Shamlo



S. Makeig et al. (2011)

I gaped ...
I tossed ...
I jolted ...
I ducked
I swerved ...

Who

I reached ...
I threw
I ran ...
pointed ...
I shot ...
I screamed ...
I am I?

am I?

I realized that ...

It struck me that ...

I wondered ...

All of a sudden ...

Distributed Brain Dynamic Events

I noticed that ...

I decided that ...

It occurred to me that ...

I imagined ...

I searched the scene for ...

I realized that ...

It struck me that ...

I wondered if ...

All of a sudden ...

I looked to see if ... The feeling hit me like ...

I noticed that ...

I thought again

I decided that ...

It occurred to me that ...

I imagined ...

I searched my memory for ...

I winked to let him know that ...

I bowed my head in ...

A big smile slowly spread over ...

Suddenly I stopped ...

I did a double-take: Why ...

I peered fixedly into the ...

I frowned – his claim seemed ...

I recoiled in mock horror

I nodded, while not really ...

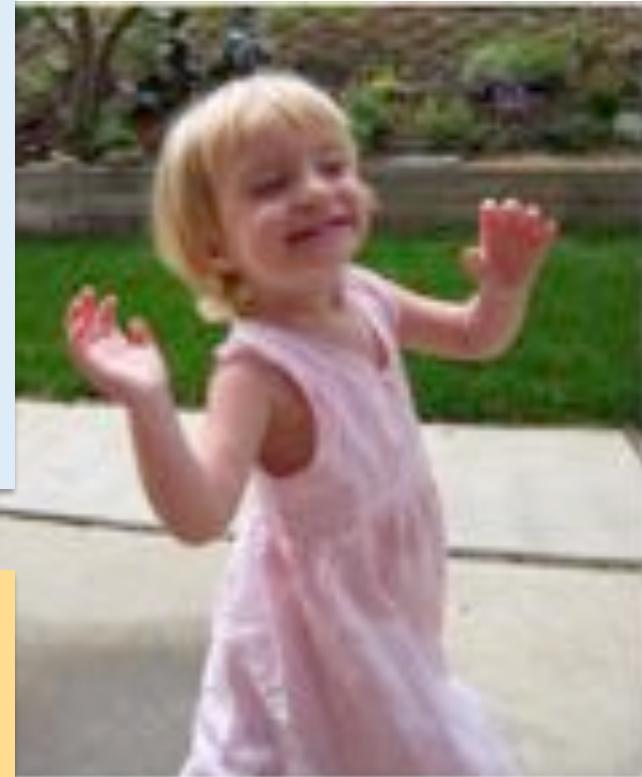
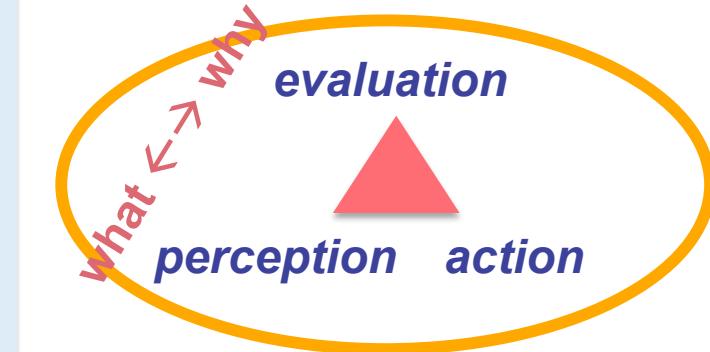
I froze, eyes open wide ...

I breathed in slowly and ...

I pursed my lips in ...

Embodied Agency

Brain processes have evolved and function to optimize the **outcome of the behavior** the brain organizes in response to **perceived challenges and opportunities.**



Brains meet the challenge of the moment!

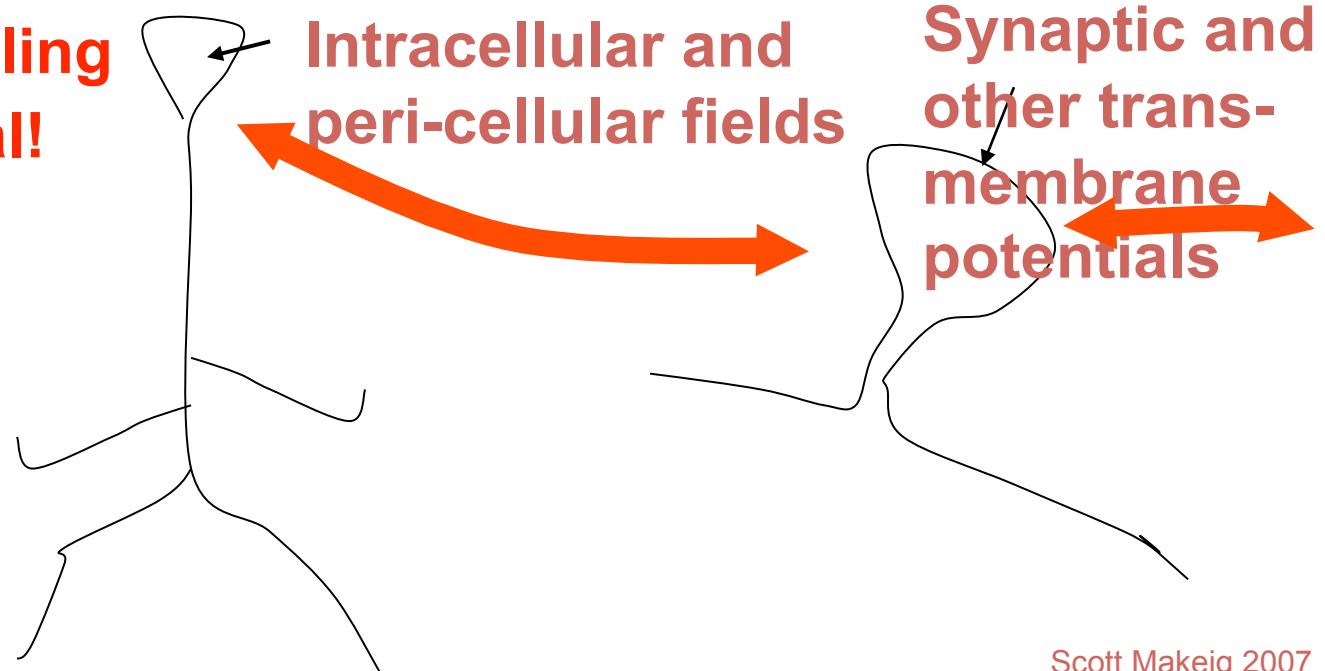
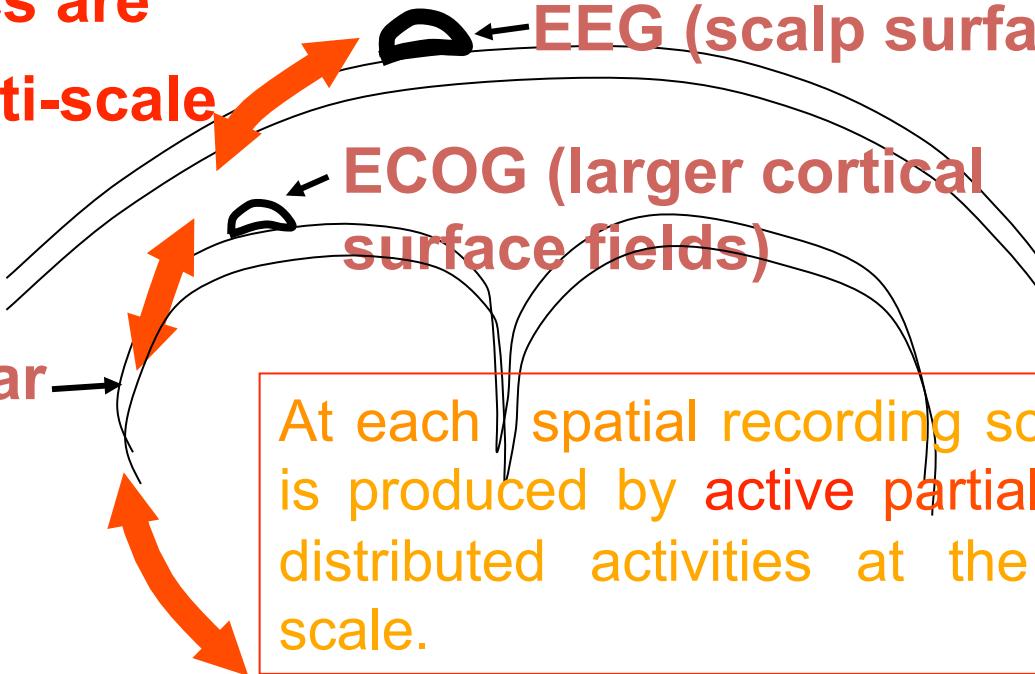
What is EEG?

Brain dynamics are inherently multi-scale

Local
Extracellular
Fields

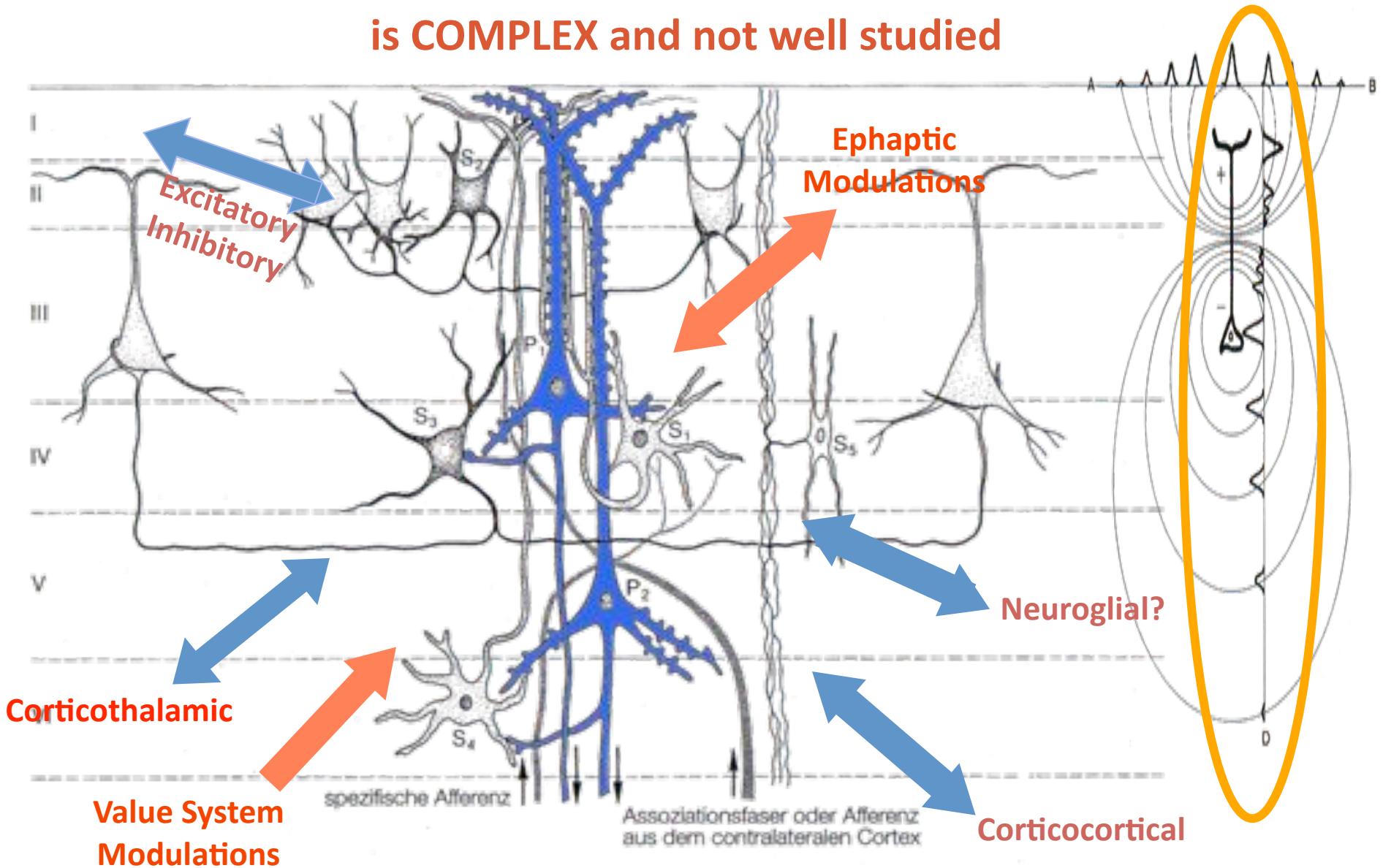
Cross-scale coupling is bi-directional!

Larger
 Smaller



Scott Makeig 2007

The generation and modulation of EEG is COMPLEX and not well studied



Functional Brain Imaging

Hemodynamic imaging
= imaging brain
Energy

Direct 3-D inverse model,
but quite slow & indirect

Electromagnetic imaging

= imaging local cortical

Synchrony

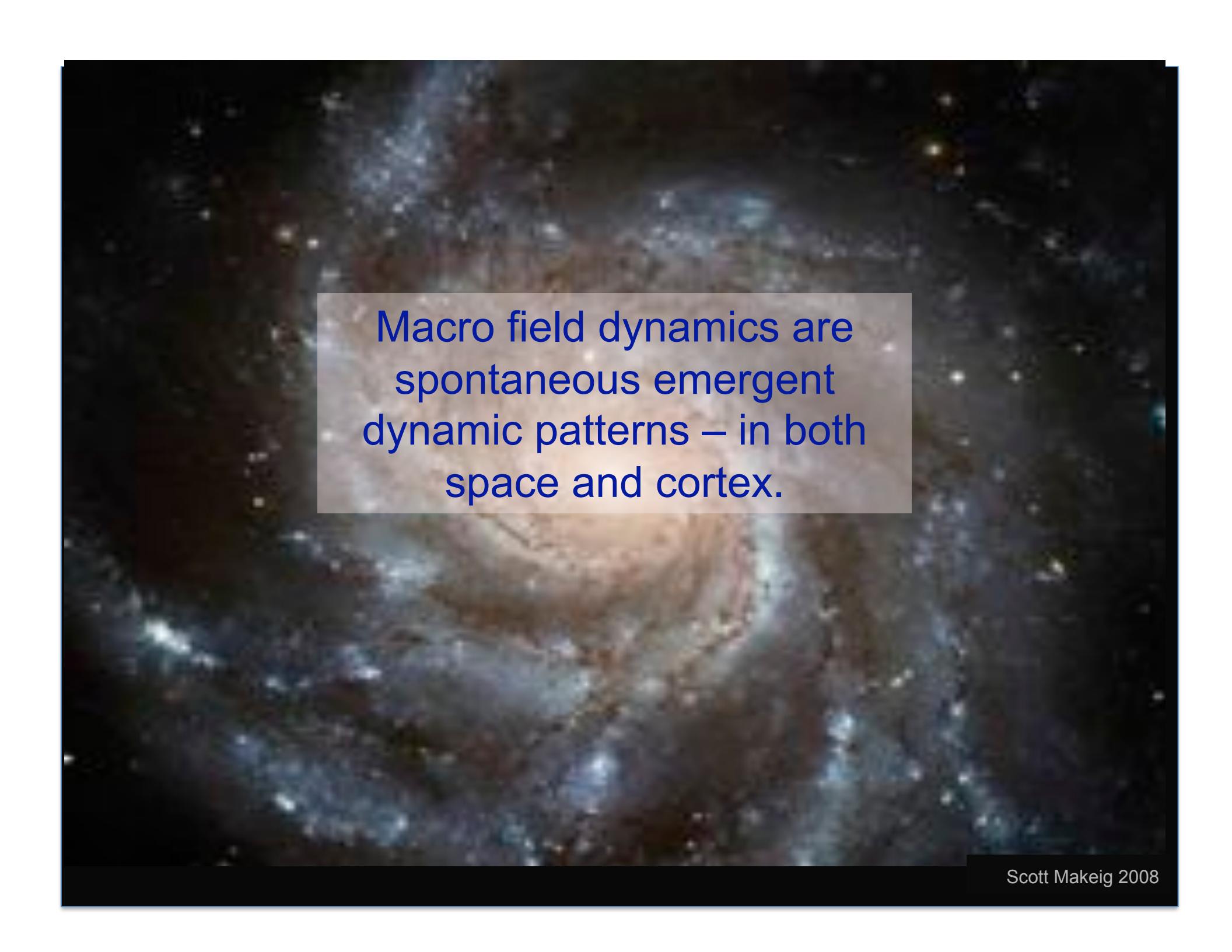
3-D imaging requires model,
but quite fast & direct measure
of one aspect of neural activity.

Phase cones (Freeman)

Avalanches (Plenz)





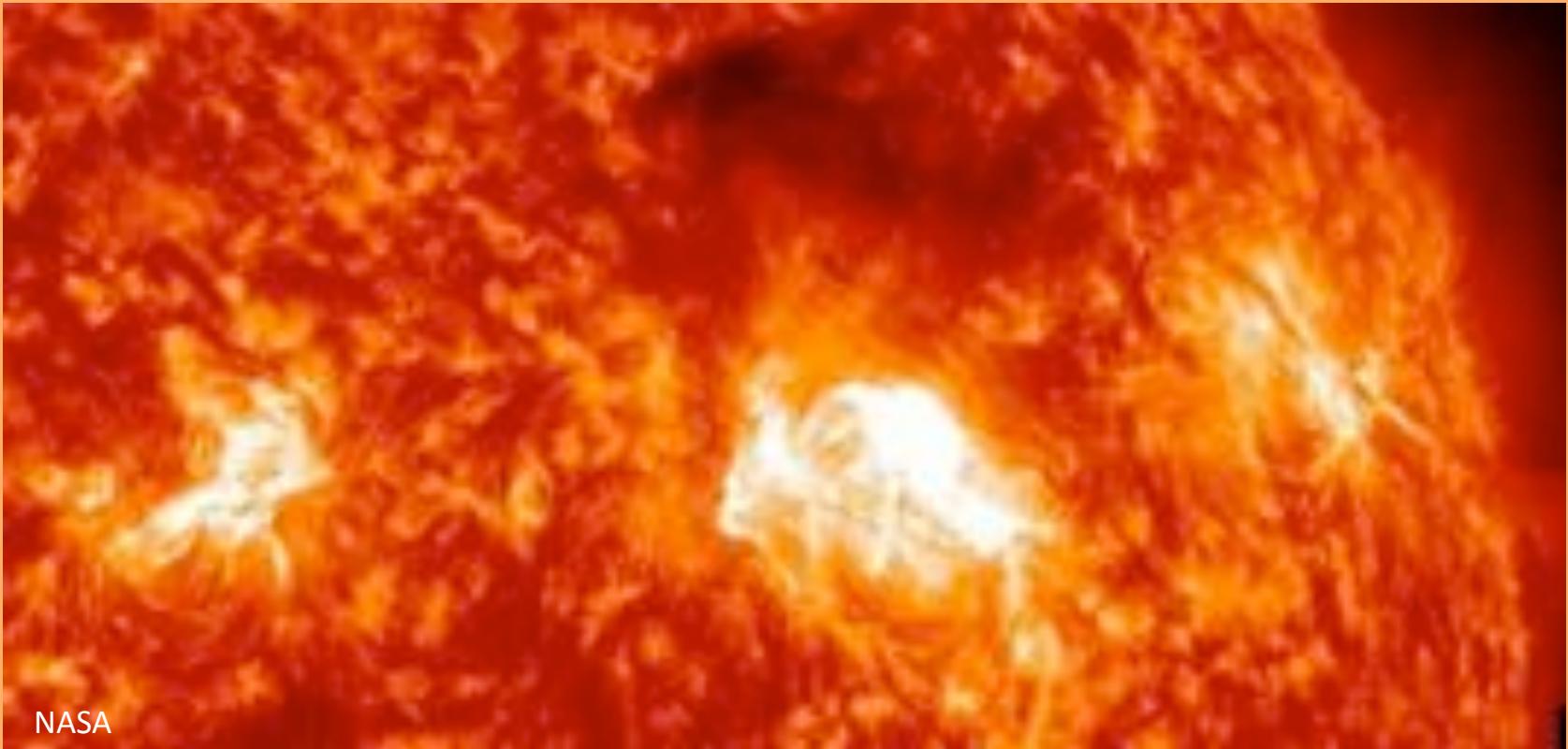


Macro field dynamics are spontaneous emergent dynamic patterns – in both space and cortex.

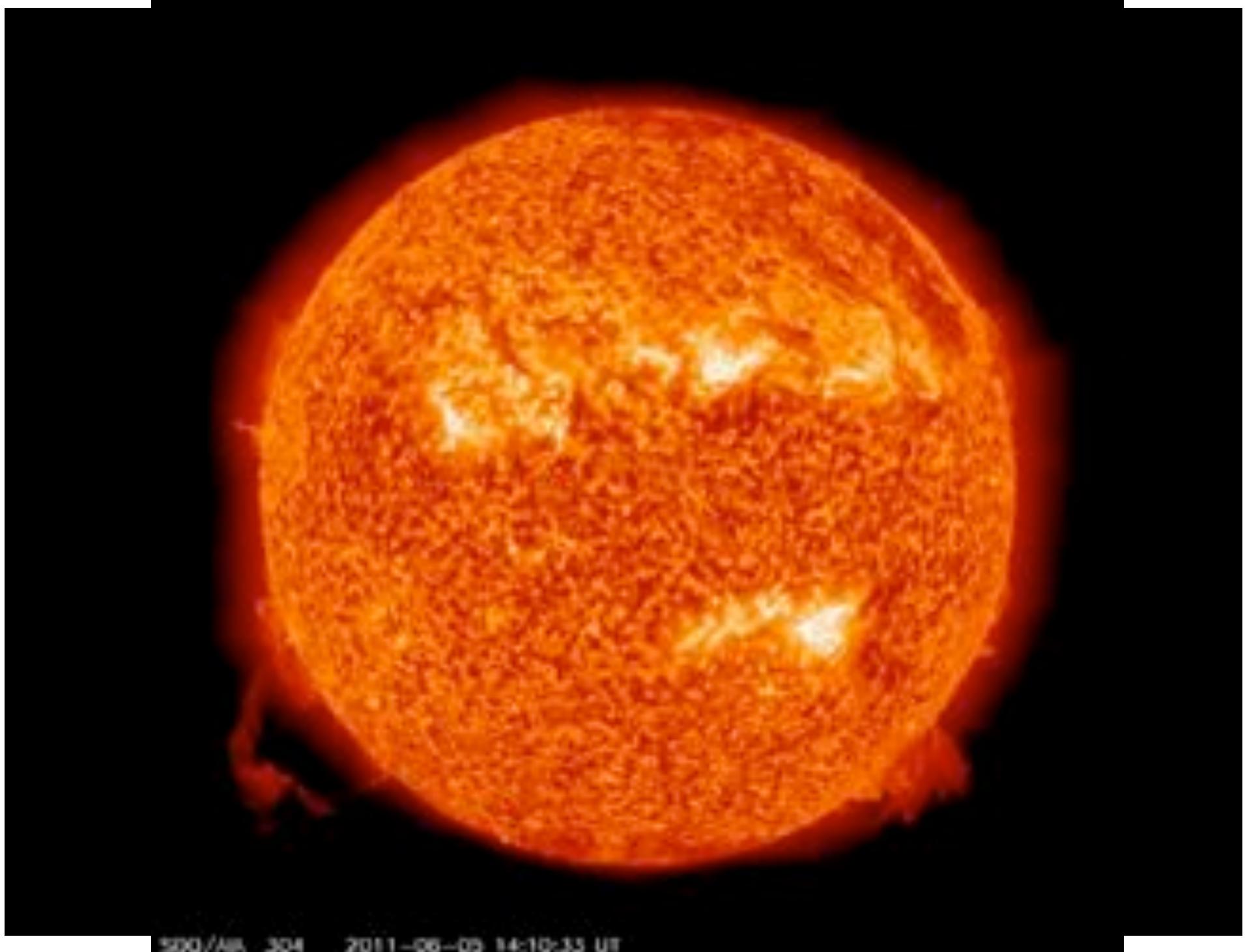


Alan Friedman

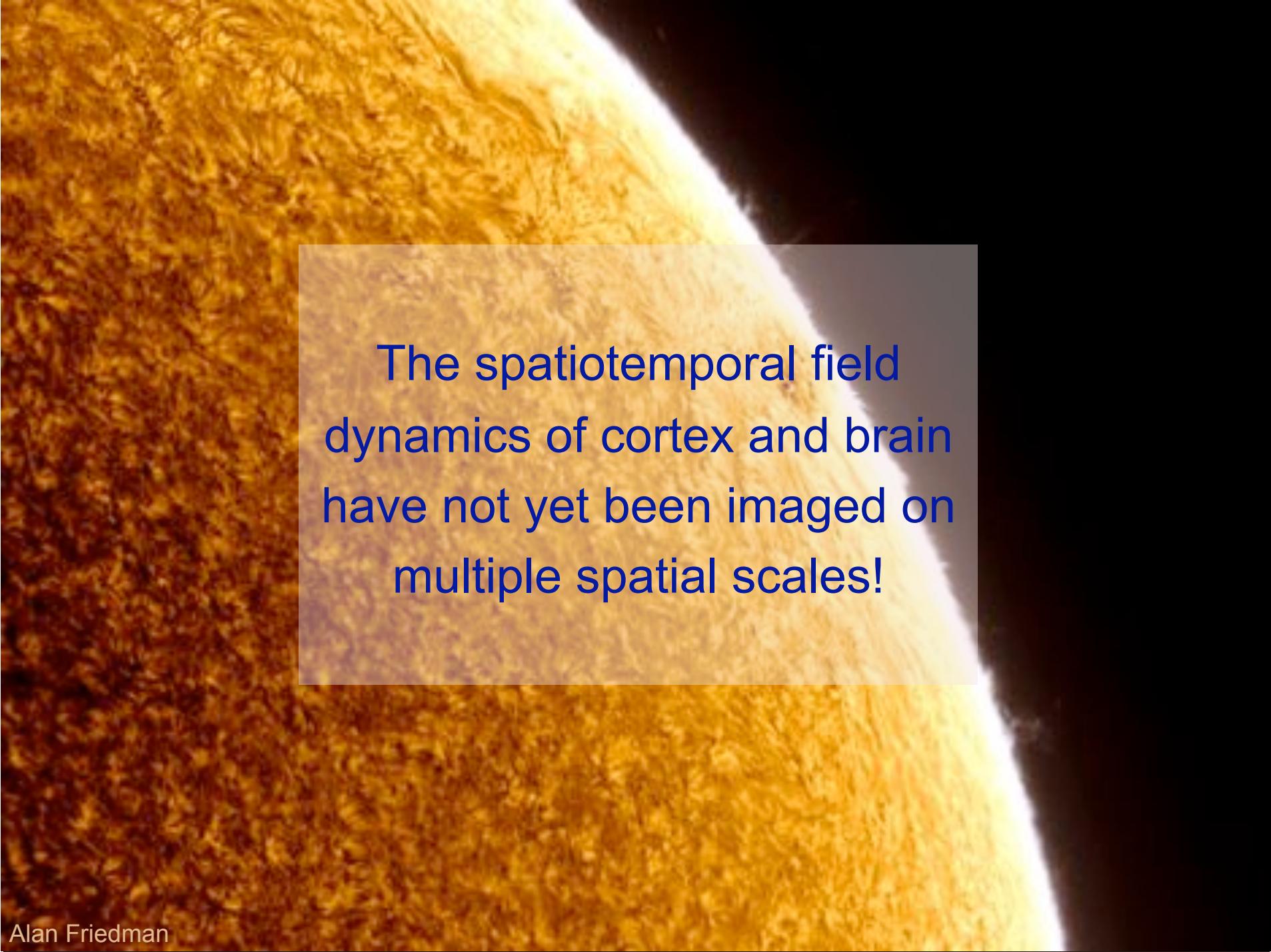
EEG Sources are emergent cortical domains of local field synchrony



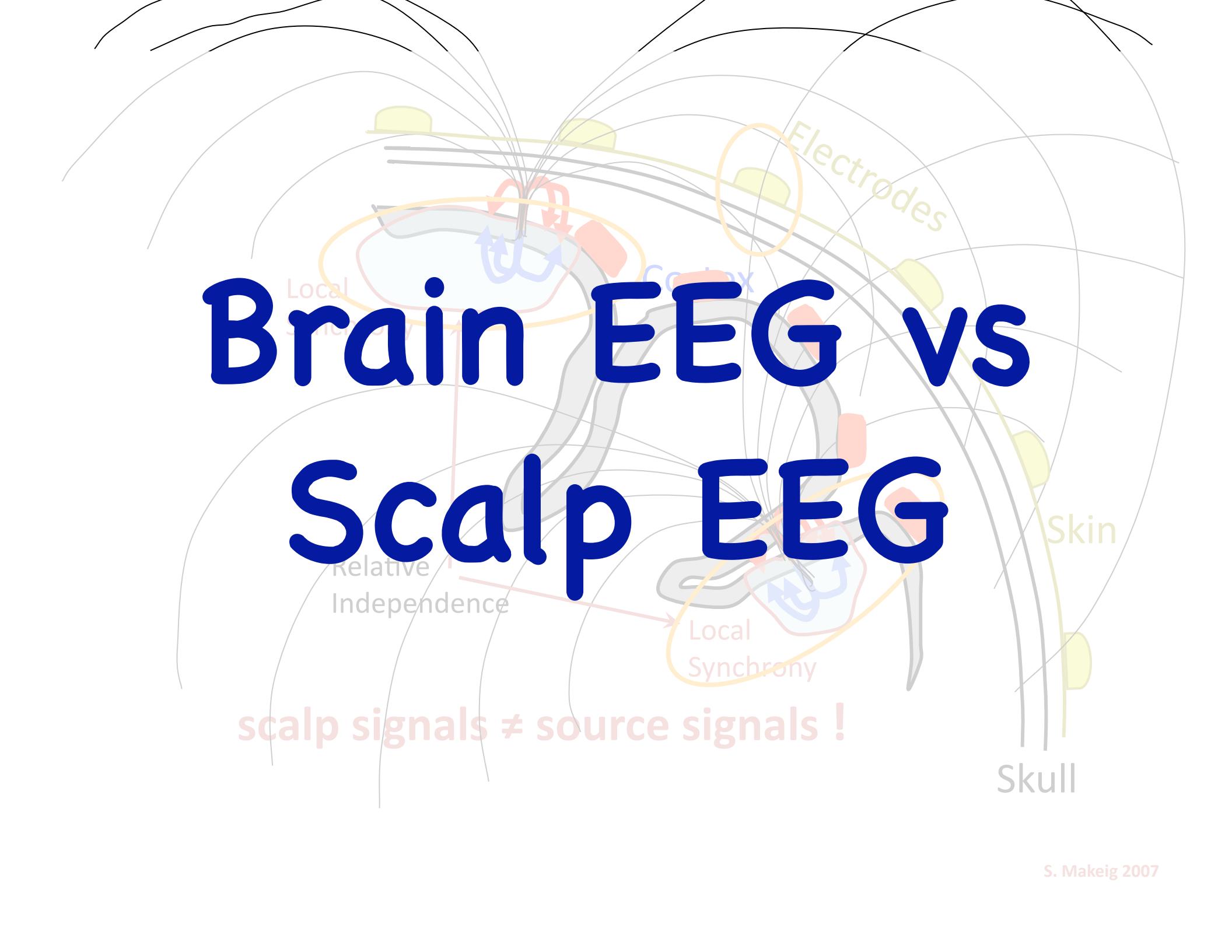
NASA



SDO/AIA 304 2011-06-09 14:10:33 UT



The spatiotemporal field
dynamics of cortex and brain
have not yet been imaged on
multiple spatial scales!



The diagram illustrates the complex process of EEG signal generation and measurement. It shows a cross-section of a head with various layers: skin, skull, and cortex. Multiple colored arrows (red, blue, green) represent different neural signals originating from specific regions of the cortex. These signals travel through the skull and reach the scalp surface. Electrodes, depicted as yellow pads, are placed on the scalp to detect these surface signals. Labels include 'Electrodes' at the top right, 'Skin' on the right side, 'Skull' at the bottom right, 'Cortex' in the center, 'Local Synchrony' with an arrow pointing to a red signal loop, 'Relative Independence' with an arrow pointing to a blue signal loop, and 'Local Synchrony' again near the bottom left. The title 'Brain EEG vs Scalp EEG' is prominently displayed in large blue letters across the center of the diagram.

Brain EEG vs Scalp EEG

scalp signals \neq source signals !



Local
Synchrony

Cortex

Relative
Independence

Local
Synchrony

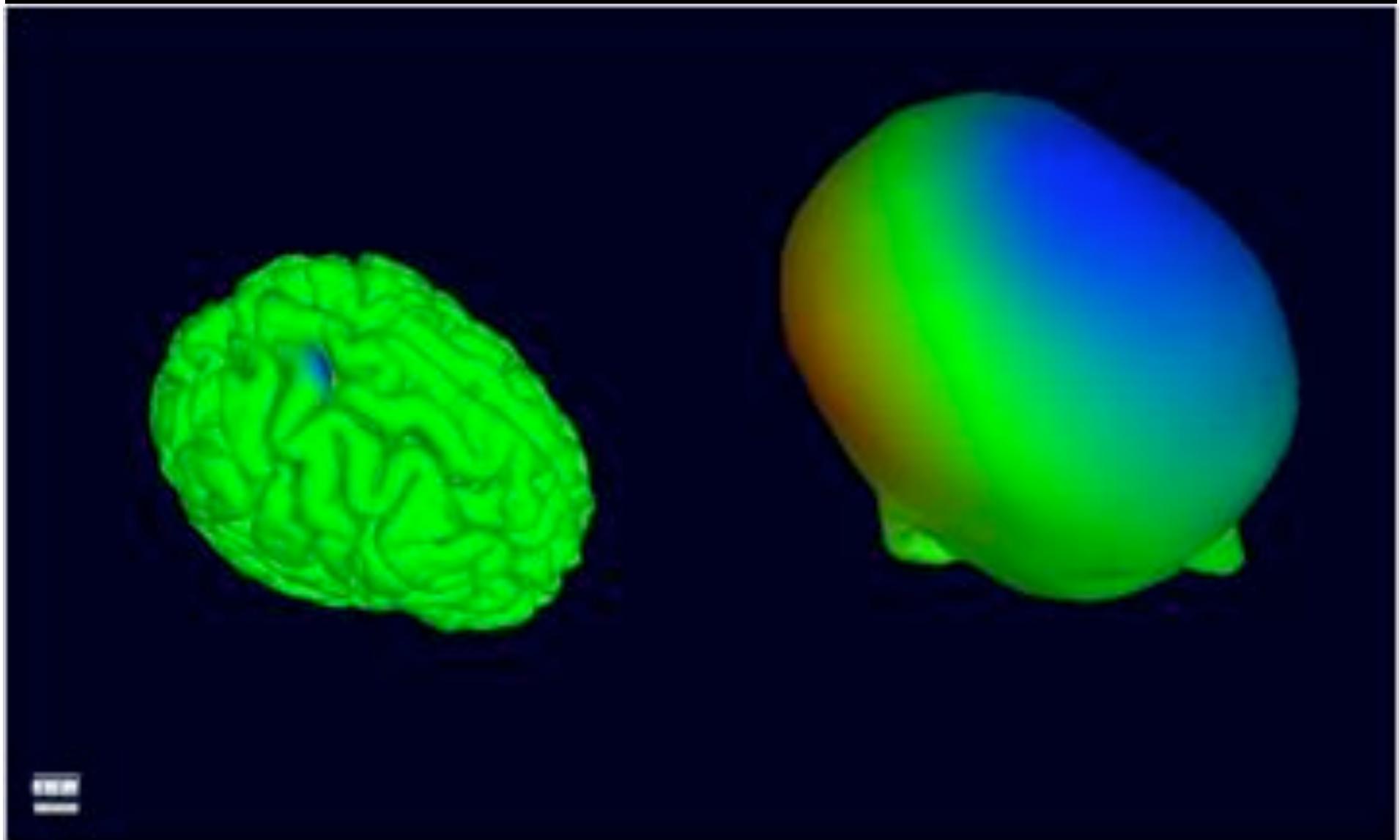
Electrodes

Skin

Skull

scalp signals \neq source signals !

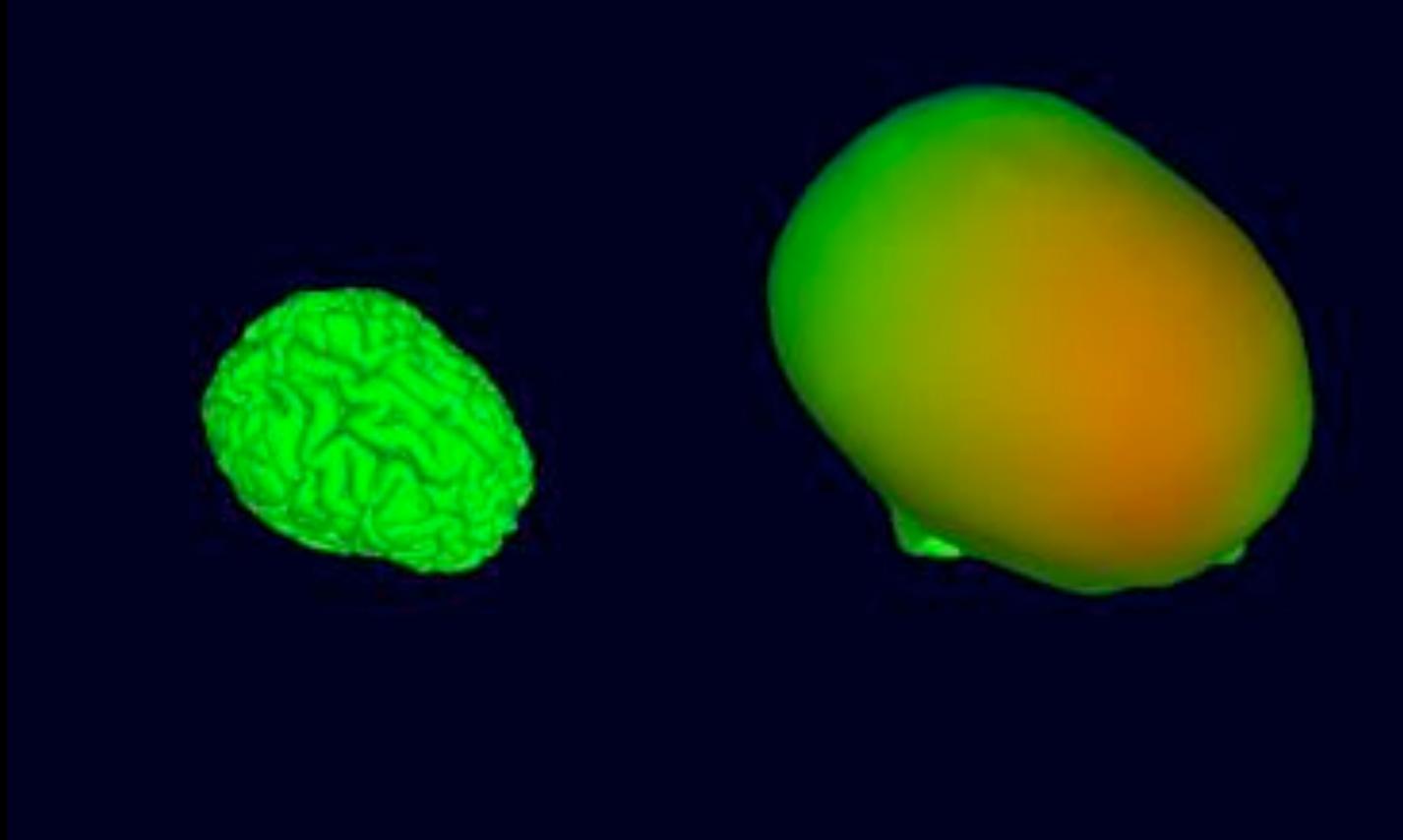
The very broad EEG point-spread function



Single source domain

Akalin Acar & Makeig 2010

The very broad EEG point-spread function



Effects of non-brain artifacts on scalp EEG



Without non-brain sources



Including non-brain sources



Electromagnetic source localization using realistic head models

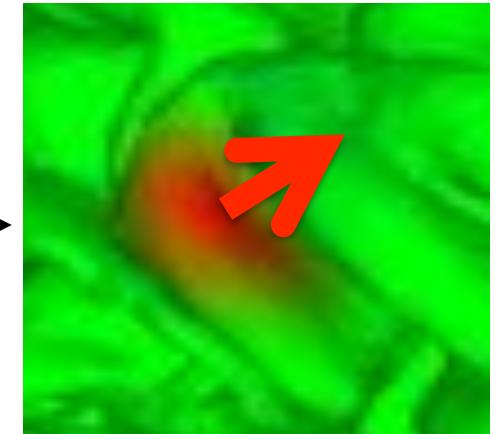
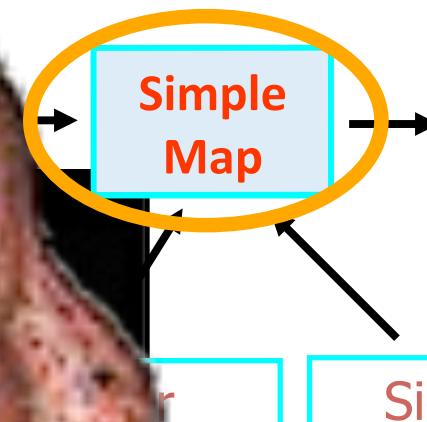


MRI

Proto Segmentation



EEG/MEG



Source
Estimate



MICRO



SPIKES

LFP

ECOG

EEG

MACRO

~1,000,000 GHz

~1 MHz

BRAIN ← → BEHAVIOR ?

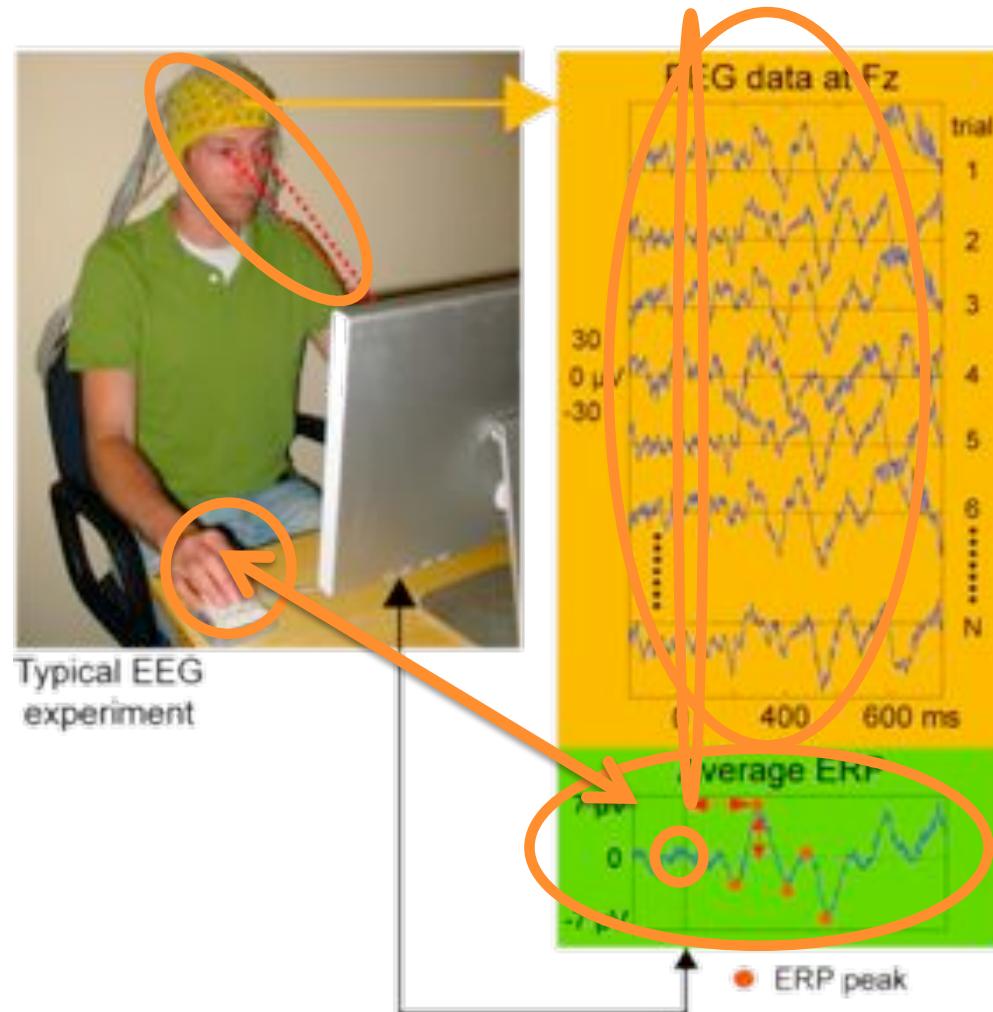
Recorded !?

ERP

RT

~1 Hz

Studying 'cognitive perception' using ERPs



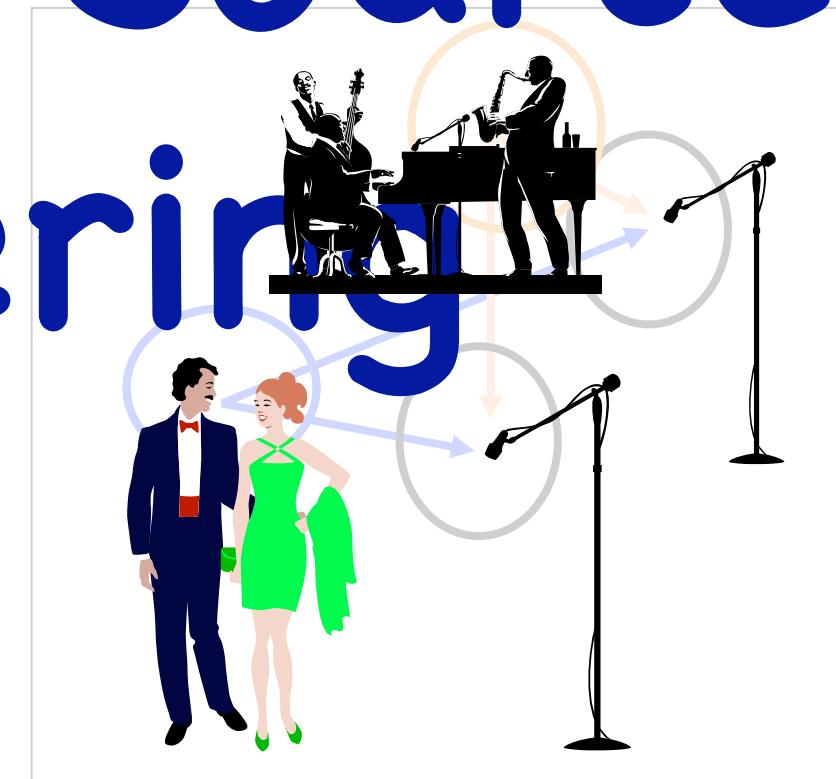
Conceptual legacies of single sensor response/rate averaging

- Reduction of the time series data at each channel to a **single average-response (ERP) time series.**
- Reduction of the data collected at each **channel** to an **isolated spatial point process.**

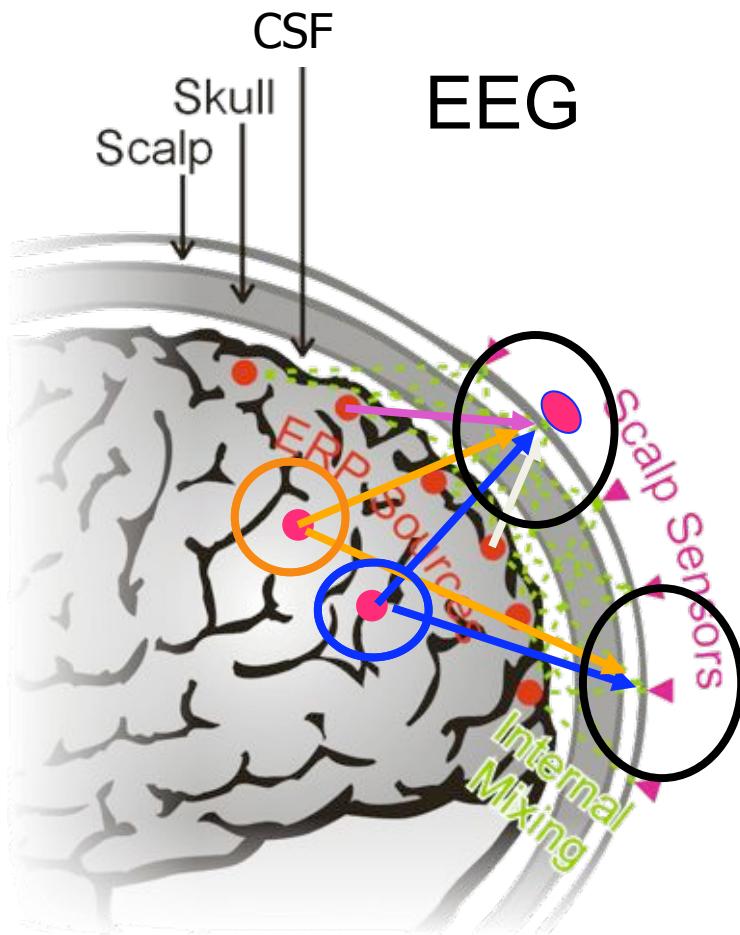
How to capture more of the event-related brain dynamics in high-density EEG data?

Blind EEG Source Separation by
Independent Component Analysis

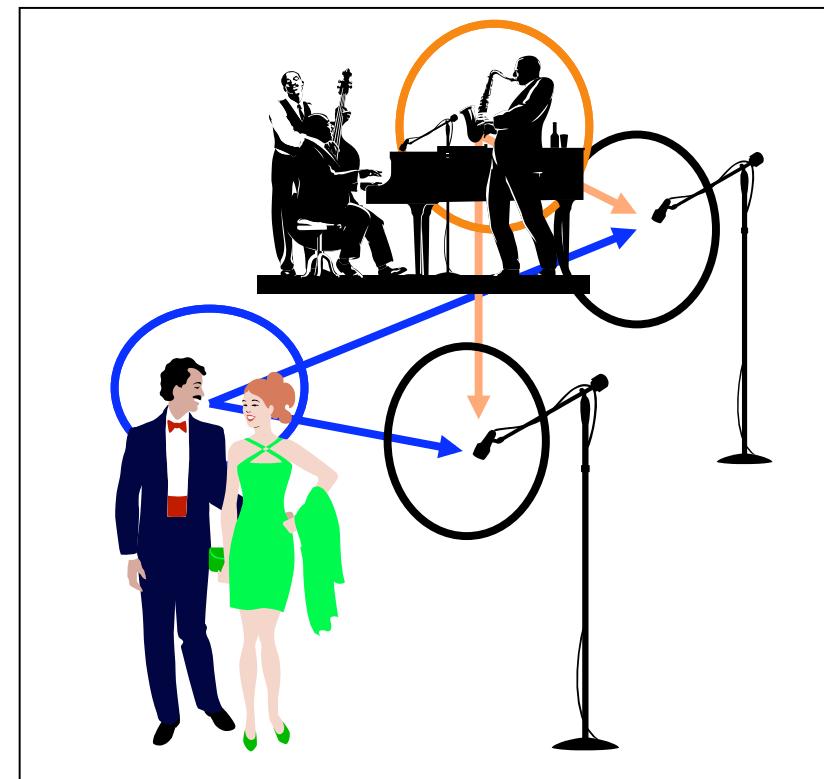
Spatial Source Filtering



Blind EEG Source Separation by Independent Component Analysis



Cocktail Party



S. Makeig (2000)

Independent Component Analysis of Electromyographic Data



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Wenyi Jiang
NeuroHealth Research Center and
Computational Neurobiology Lab,
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jiang@ucsd.edu



Eric Horwitz
Howard Hughes Medical Institute and
Computational Neurobiology Lab,
The Salk Institute, P.O. Box 8580
San Diego, CA 92184-3680
horwitz@salk.edu

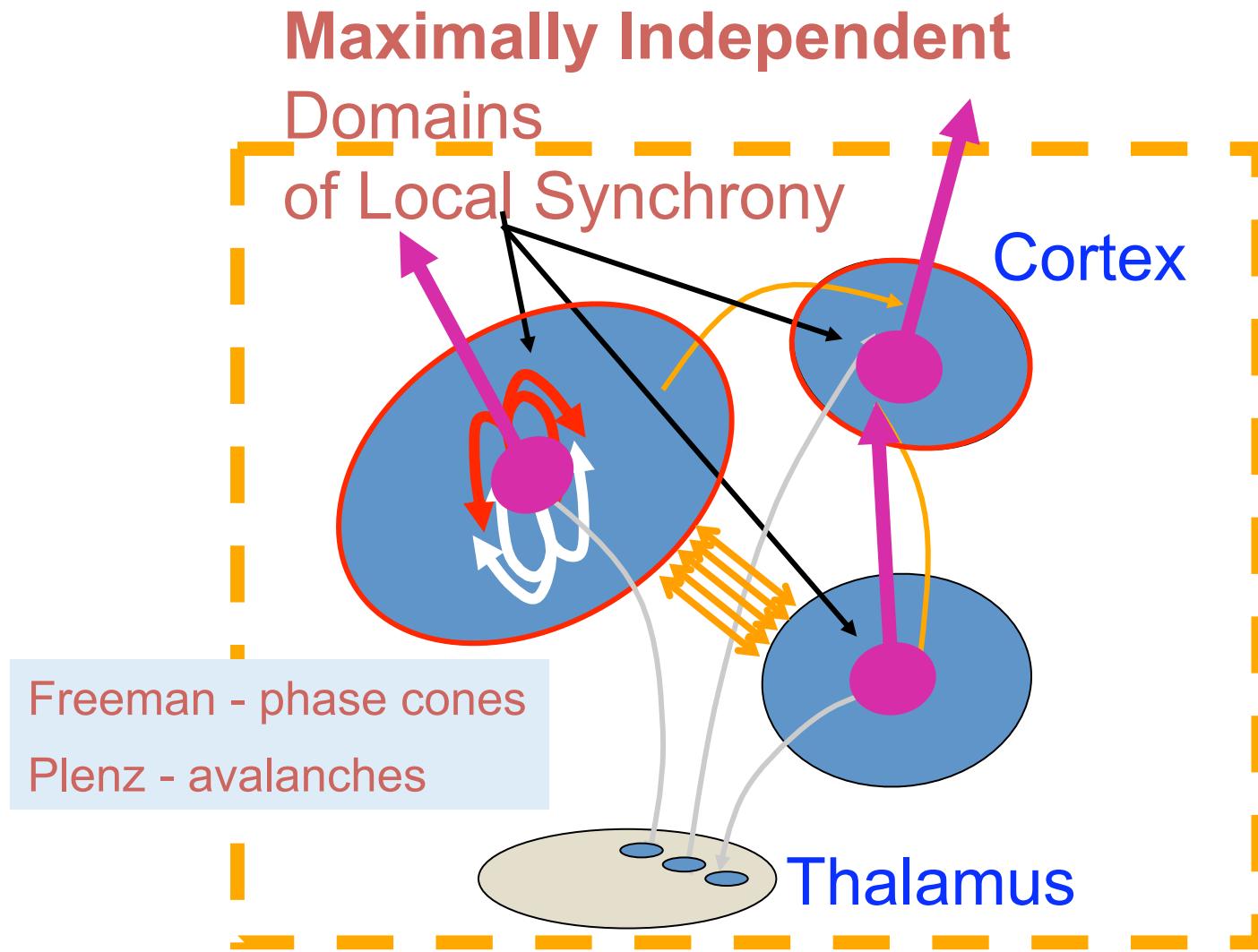
Abstract

The issue of the infomax criterion (Shabot and Makeig, 1998) was revisited from two points of view. First, the infomax criterion was evaluated from 100 pairs of the human EMG signals which were recorded within a large muscle area. This spatial recording of EMG data by volume conduction does not make significant differences between ICA

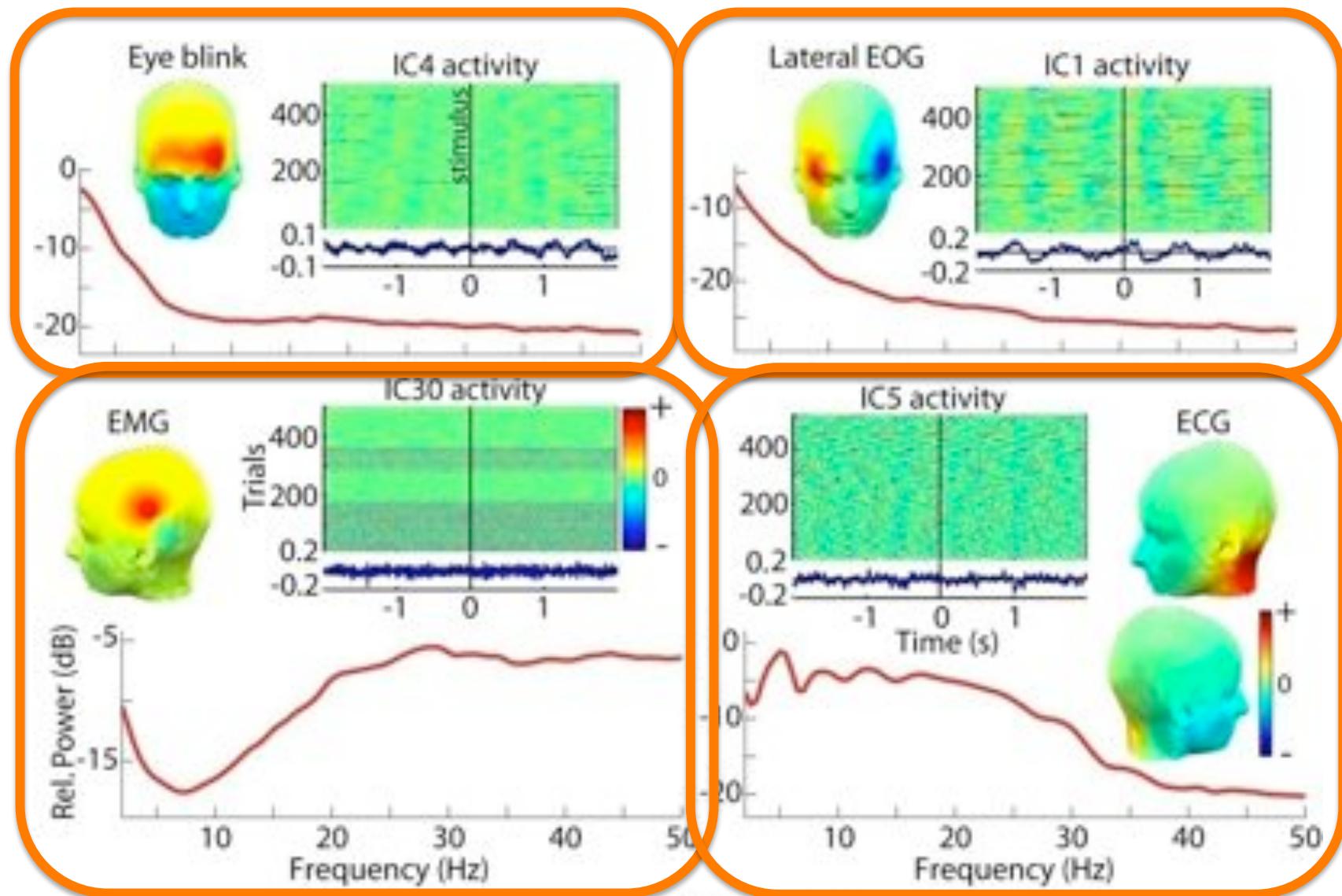
Infomax ICA

and ordinary PCA algorithms. As second and most important point, ICA was evaluated during a sustained voluntary activation task where (1) the subjects had to keep their 10 different surface areas, (2) ICA may be used to segregate different underlying EMG components that are mixed with one another from other sources. (3) ICA is capable of isolating overlapping EMG phenomena, including all joint and torso EMG and mixed by response EMG components. (4) separate EMG phenomena (e.g., muscular activities in ITCB and human) could easily can be isolated using ICA via changes in the anatomical skeletal organization between ICA-based output channels.

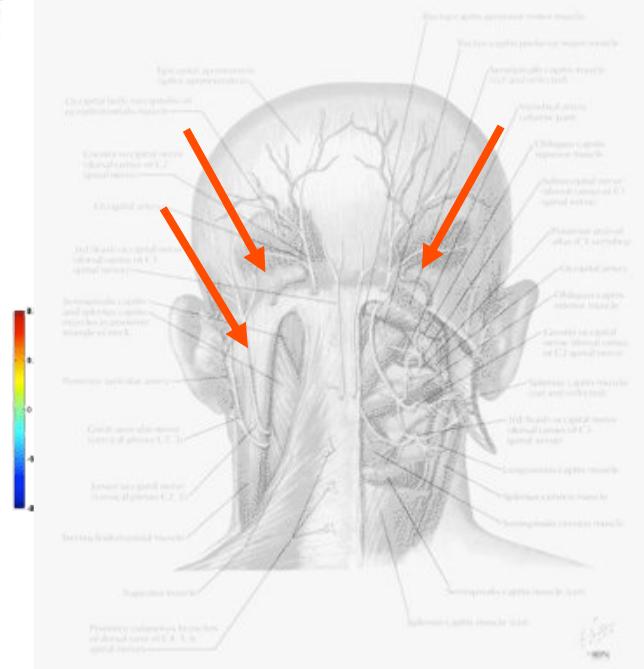
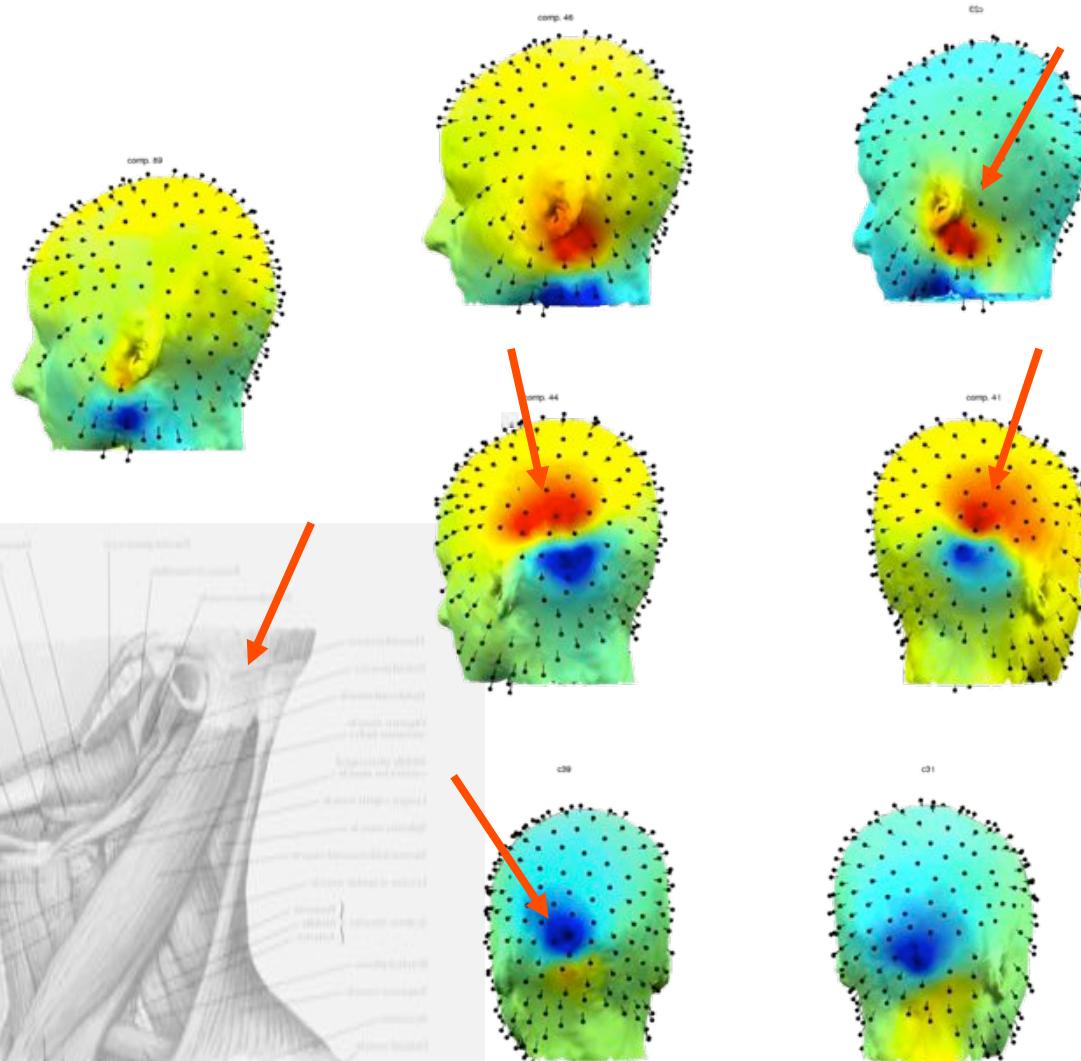
Are EEG source outputs (nearly) independent?



Some non-brain source ICs

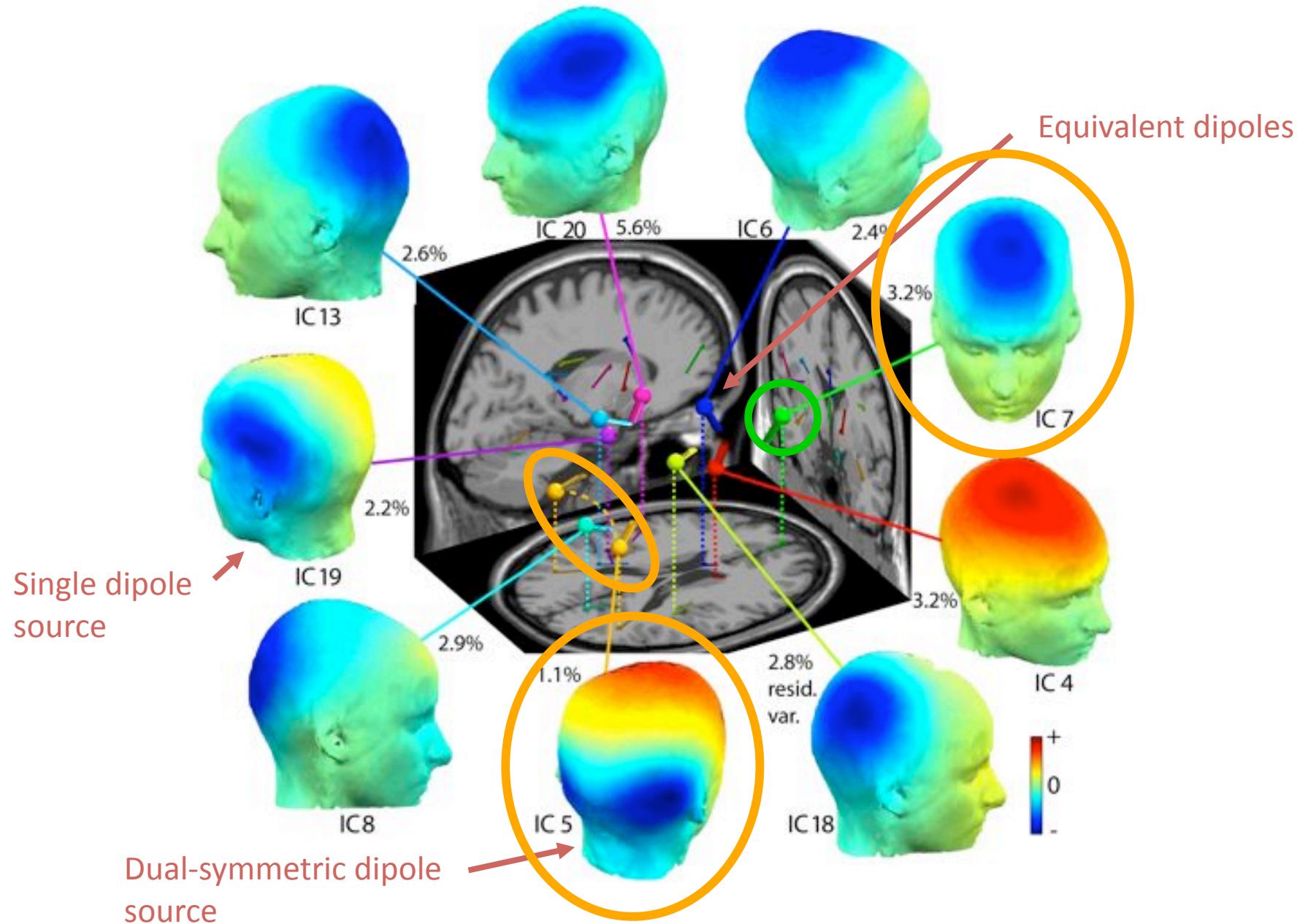


Independent muscle signals



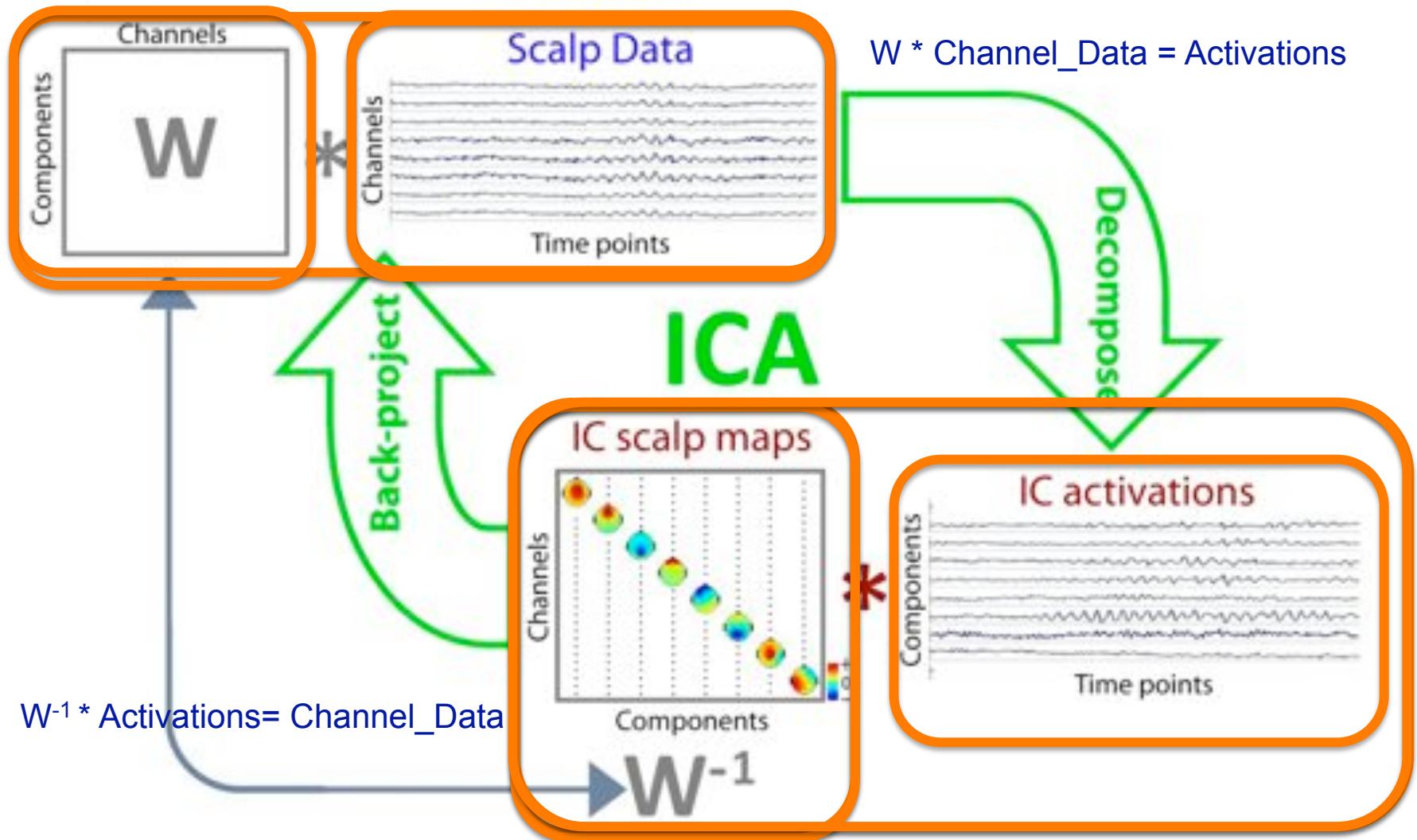
S. Makeig, J. Onton 2005

Independent brain EEG sources

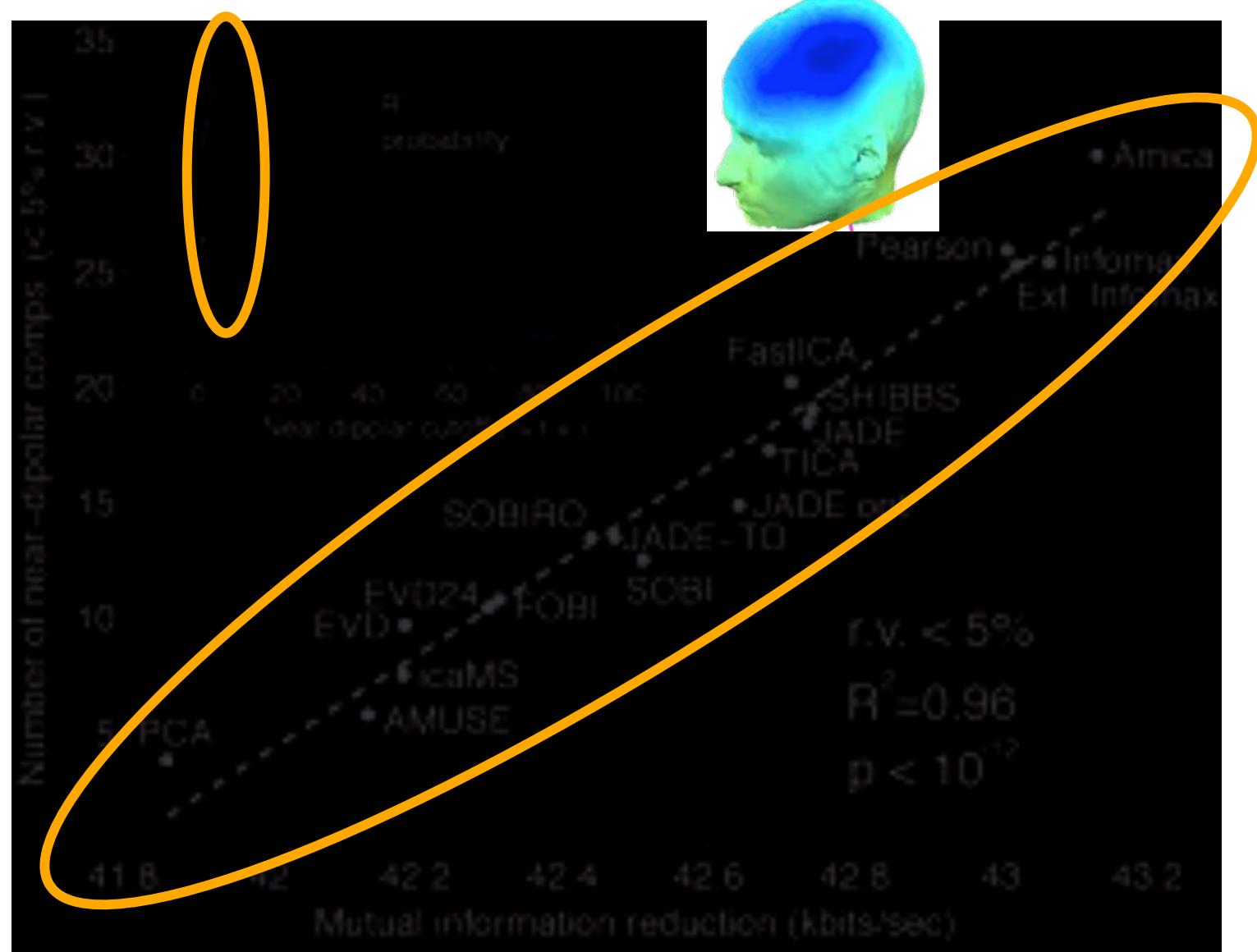


Julie Onton & S. Makeig (2006)

ICA is a linear data decomposition method

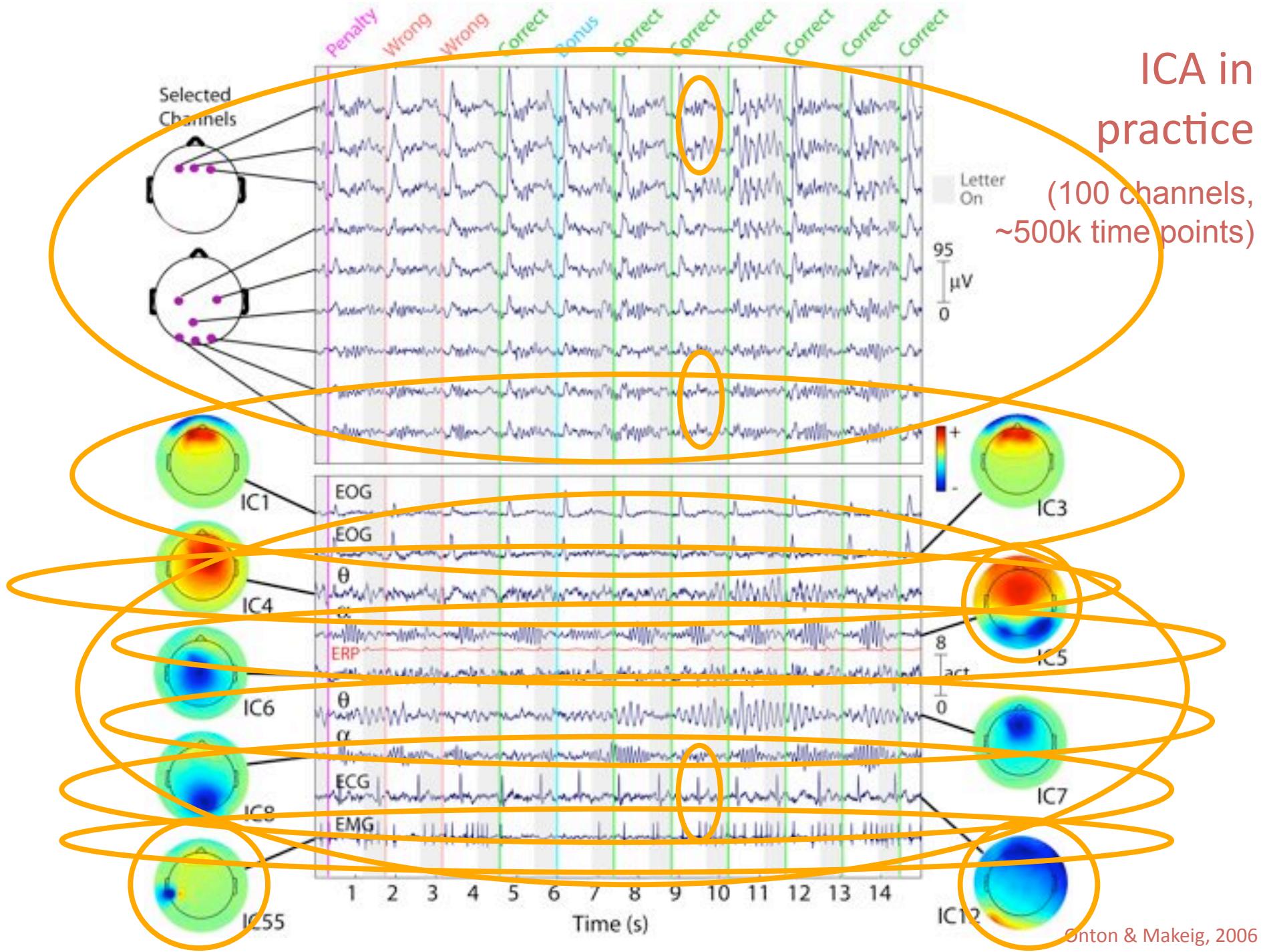


Independent Components of Human EEG are Dipolar

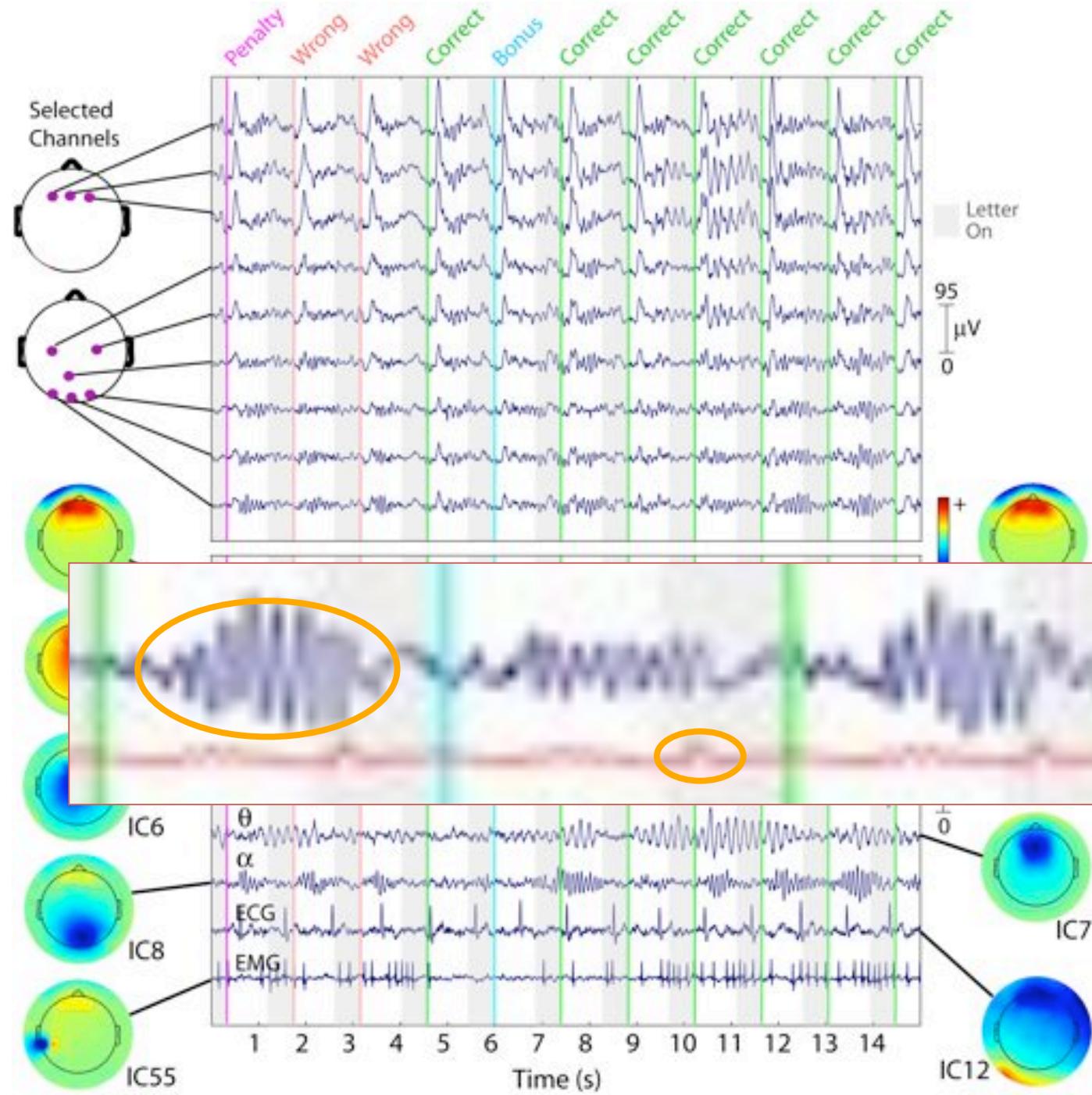


ICA in practice

(100 channels,
~500k time points)

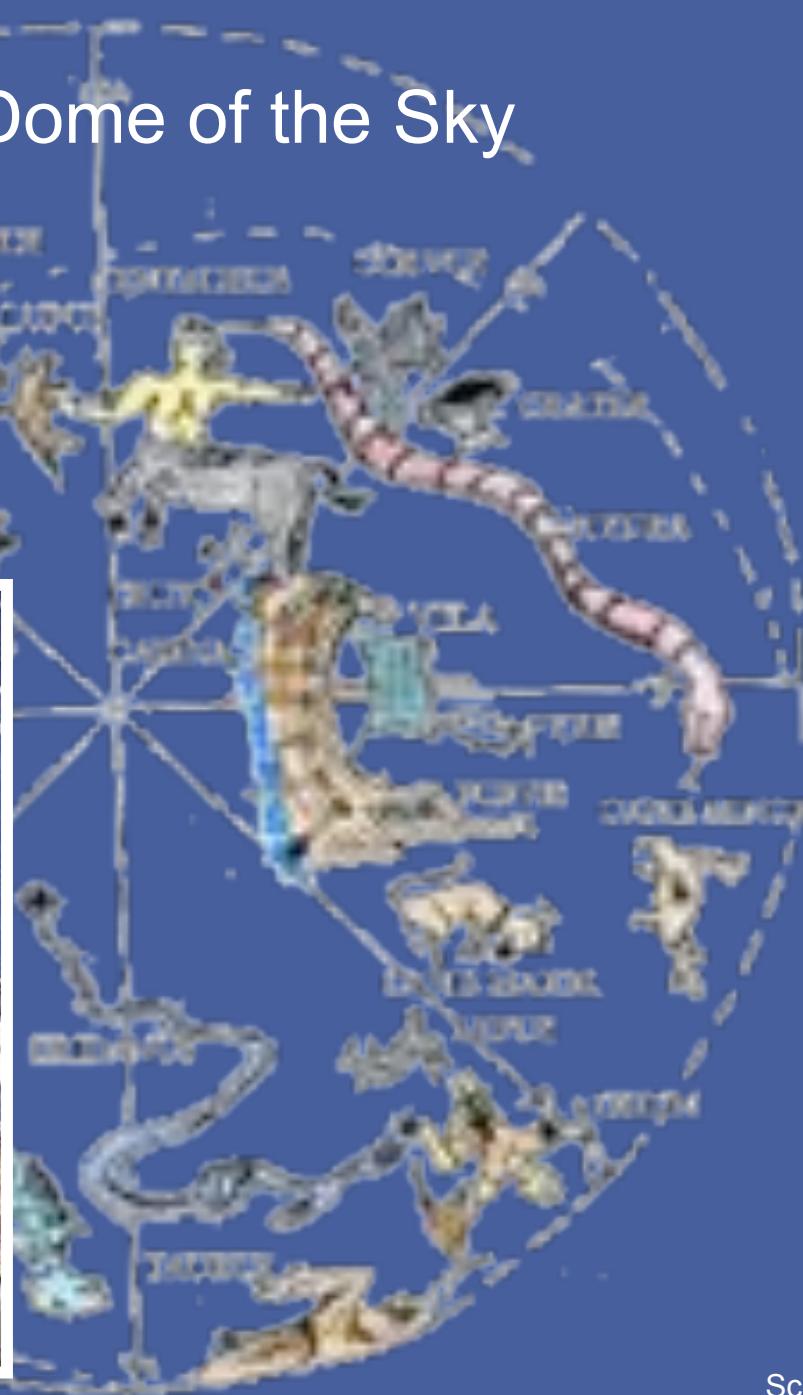


Onton & Makeig, 2006



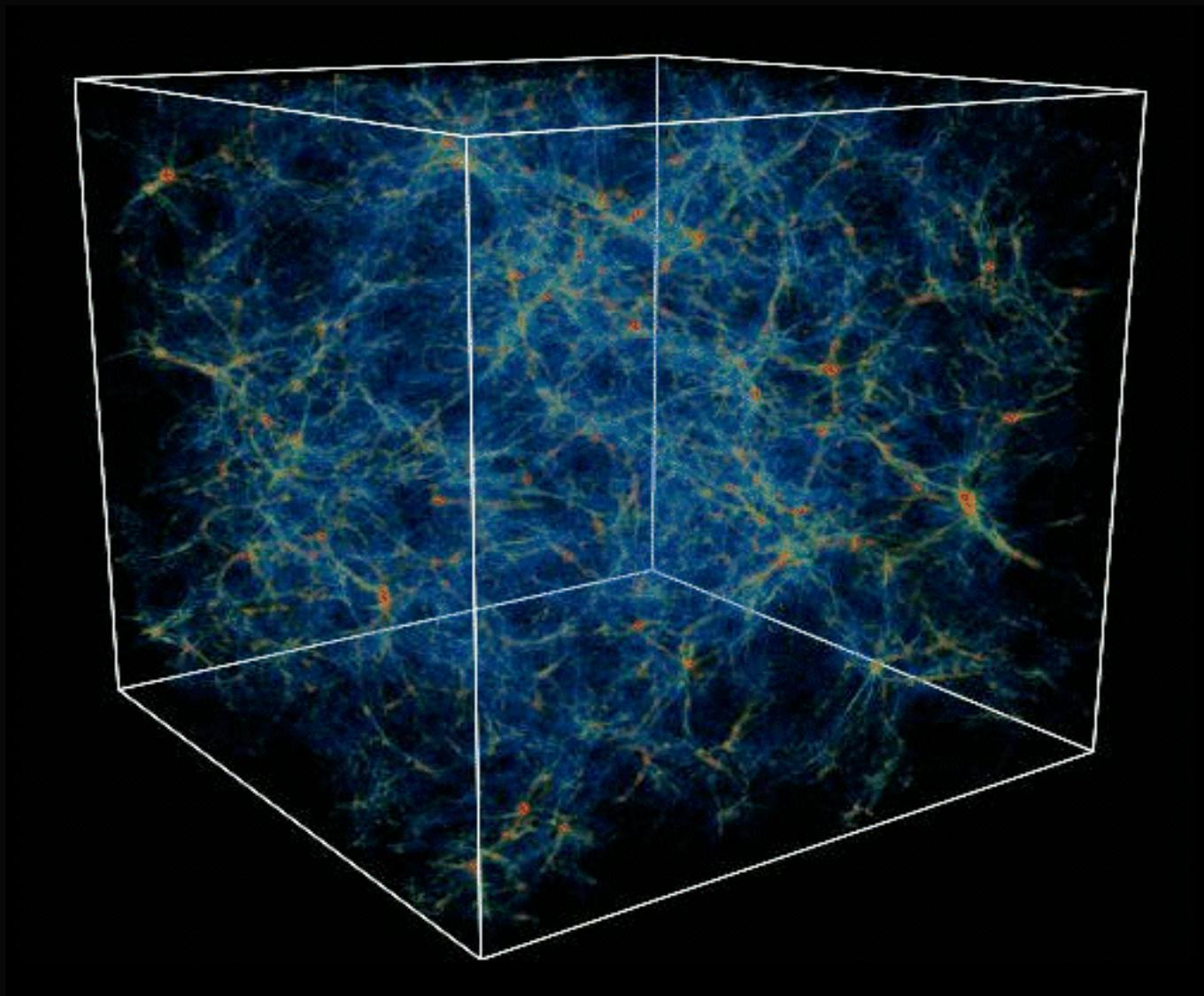
Onton, Makeig (2006)

The 2-D Dome of the Sky

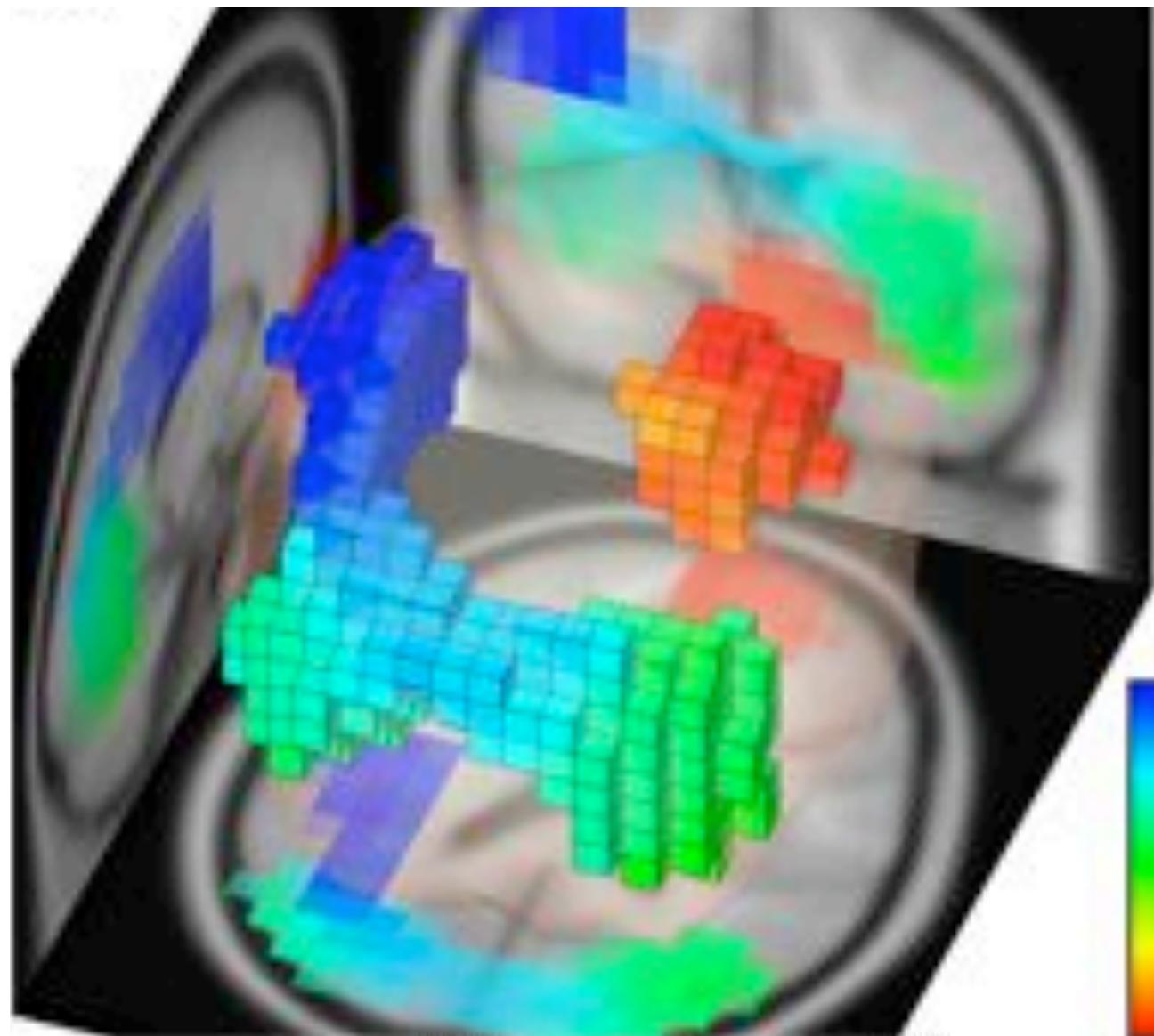


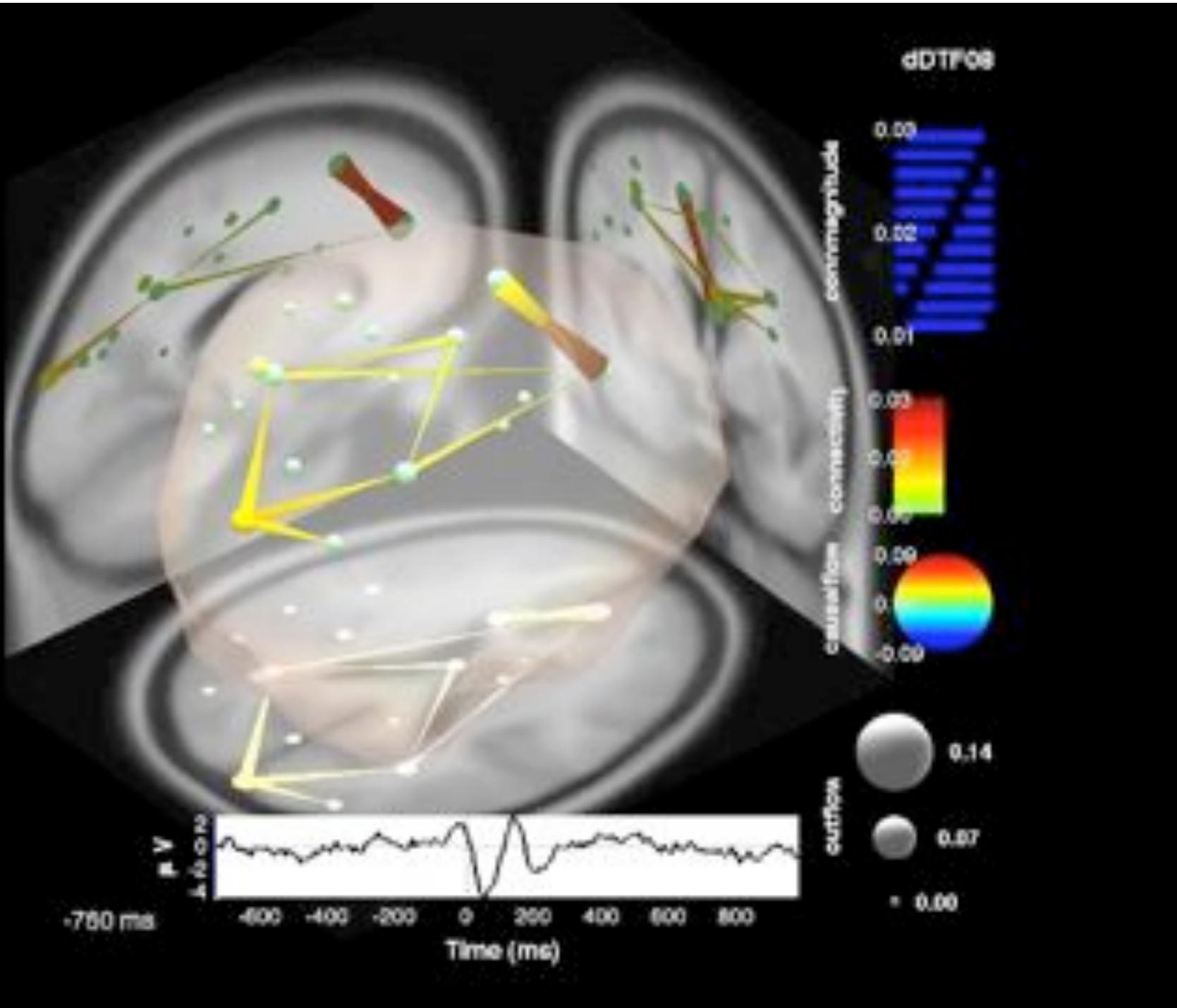
Scott Makeig 2008

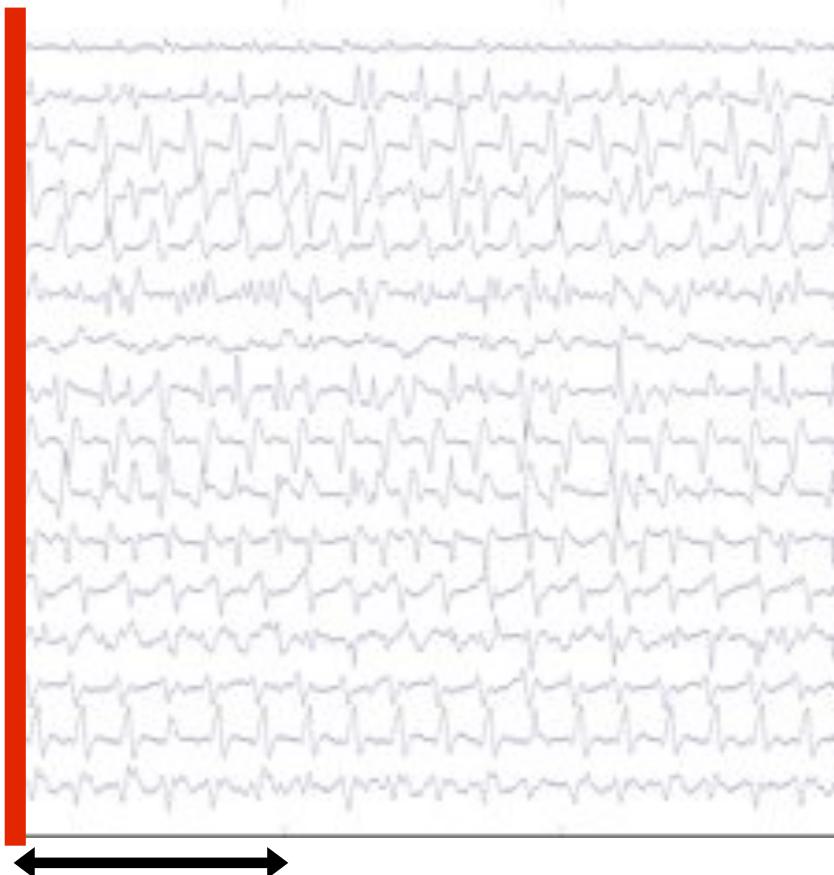
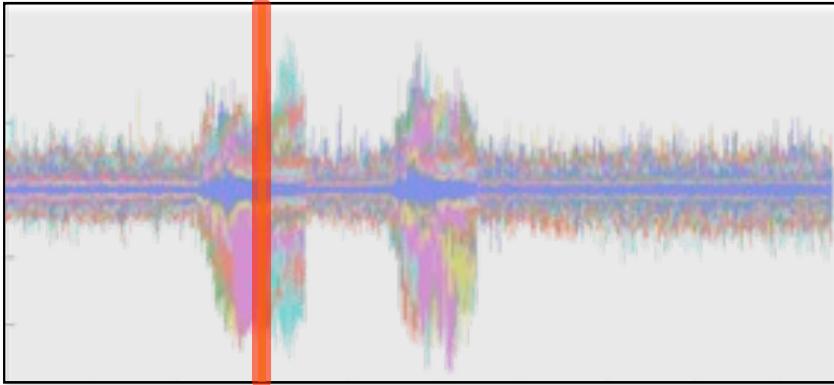
3-D structure of the Universe



Measure Projection Toolbox

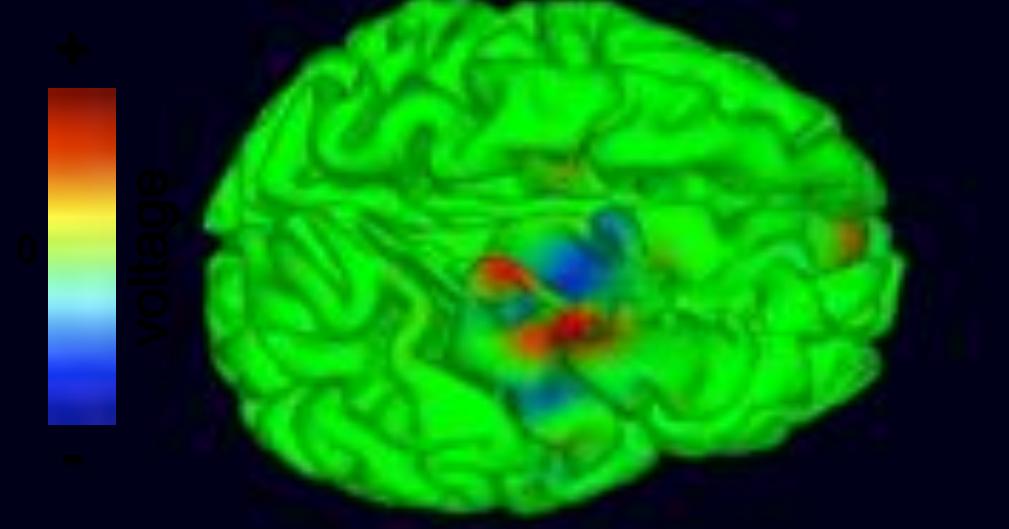






1 sec

Cortical surface potentials,
Ictal subspace
(16 ICs, SBL mapping)



Playback at 1/5 actual speed

T Mullen, 2011



A grayscale photograph showing the back of a person's head. Numerous small, circular electrodes are attached to the scalp in a grid-like pattern, connected by thin wires. The background is dark, suggesting a laboratory setting.

Questions please!