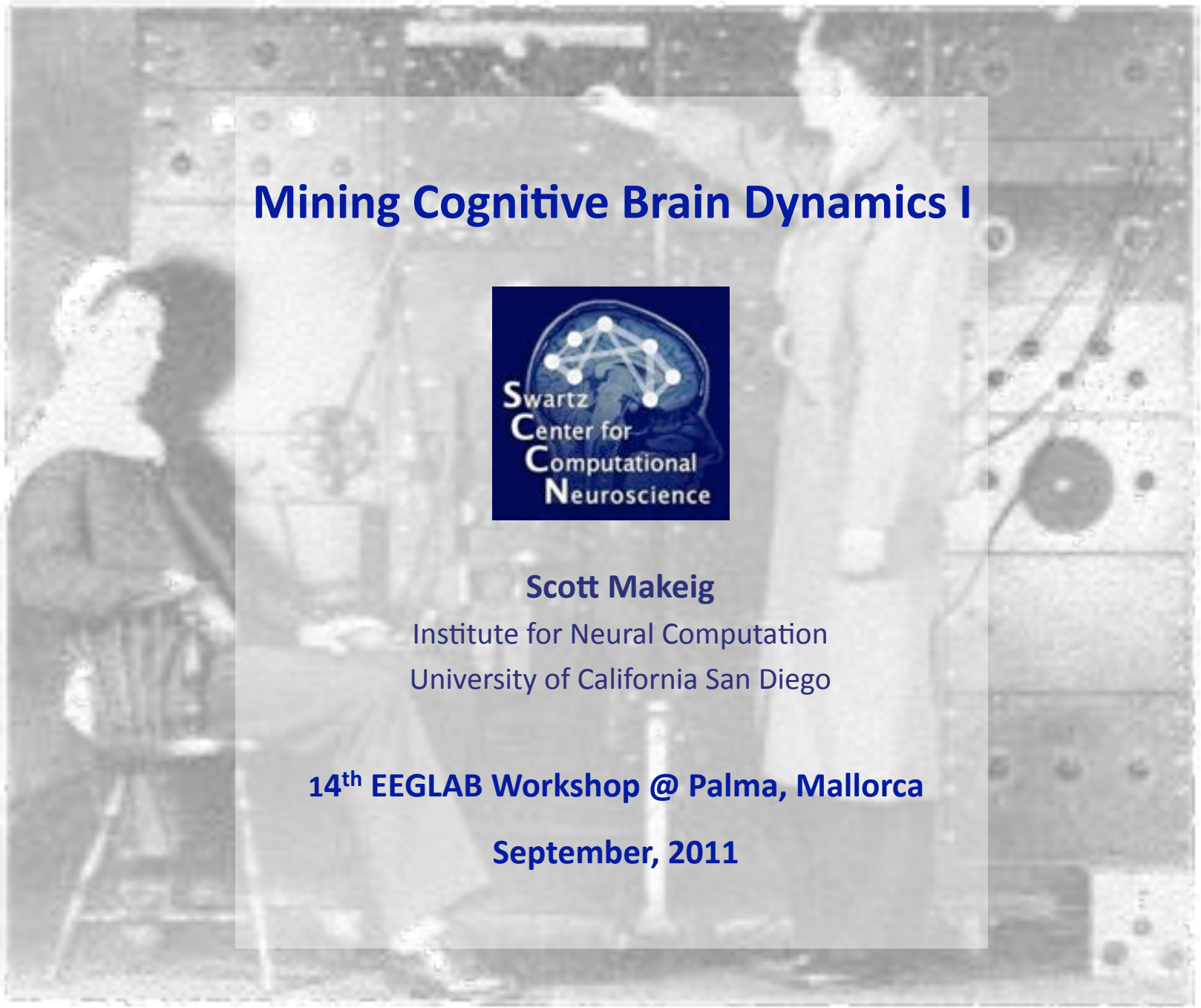


Mining Cognitive Brain Dynamics I

Scott Makeig
Institute for Neural Computation
University of California San Diego

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 …

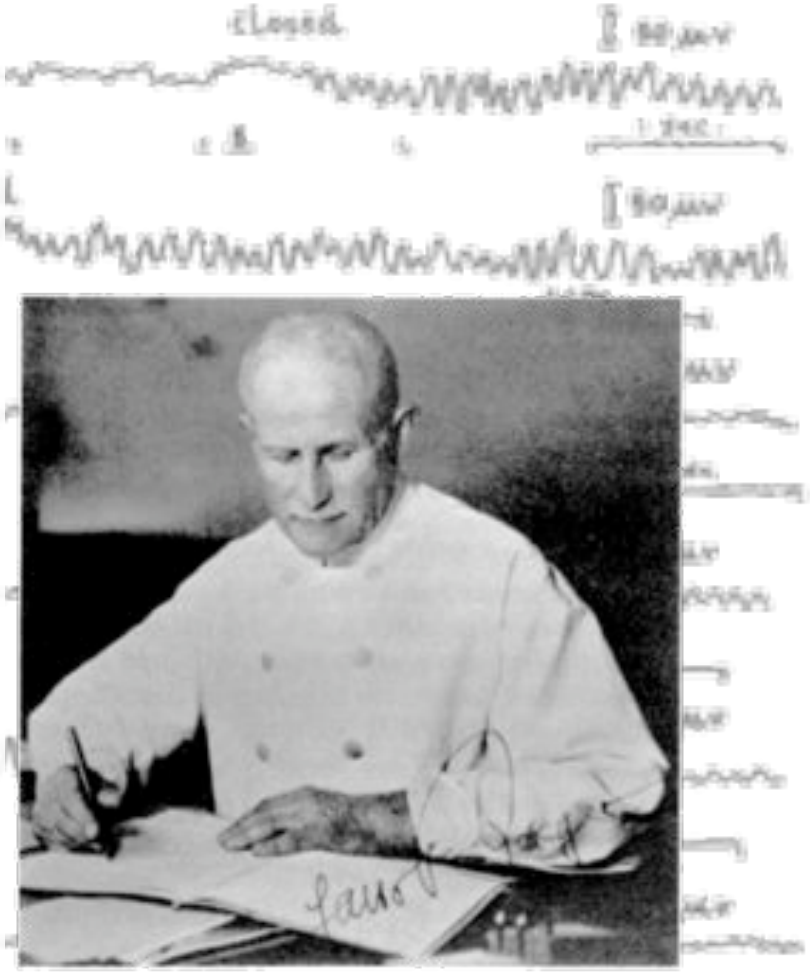


FIGURE 1–1.—Professor Hans Berger (1873–1941), neuropsychiatrist, University of Jena, Jena, Germany, first to discover and describe in 1929 a unique kind of electrical activity recorded from the brain of man, which he named the electroencephalogram (Elektrenkephalogramm).

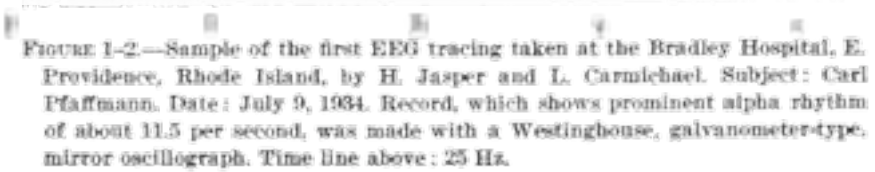
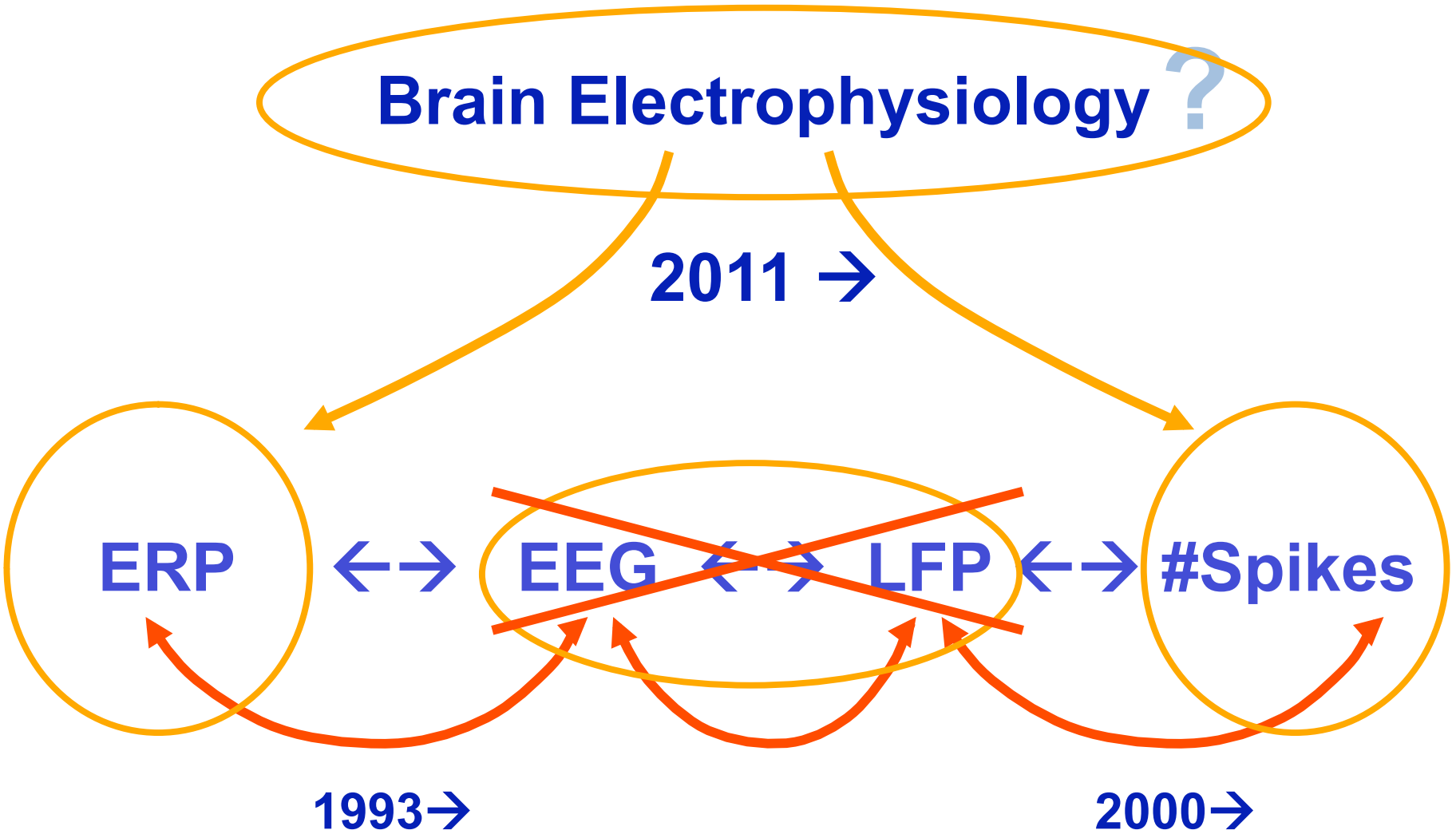


FIGURE 1–2.—Sample of the first EEG tracing taken at the Bradley Hospital, E. Providence, Rhode Island, by H. Jasper and L. Carmichael. Subject: Carl Pfaffmann. Date: July 9, 1934. Record, which shows prominent alpha rhythm of about 11.5 per second, was made with a Westinghouse, galvanometer-type, mirror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

S. Makeig 2010



S. Makeig, *TINS* 2002

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 …**

S. Makeig 2010

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	Auditory Psychophysics Psychopathology
La Jolla	@gmail.com	EEGlab is great!
Chinca	@126.com	hi!
?	@yahoo.com	LOVE OBSESSION
US Gov	@pnl.gov	
US EDU	@bethelks.edu	EEG and ERP responses to music stimuli
EU	@ucl.ac.be	Neuroimaging
US EDU	@wlu.edu	olfaction ERP
Switzerland	@student.ethz.ch	
Sweden	@neuro.ki.se	BBCI
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

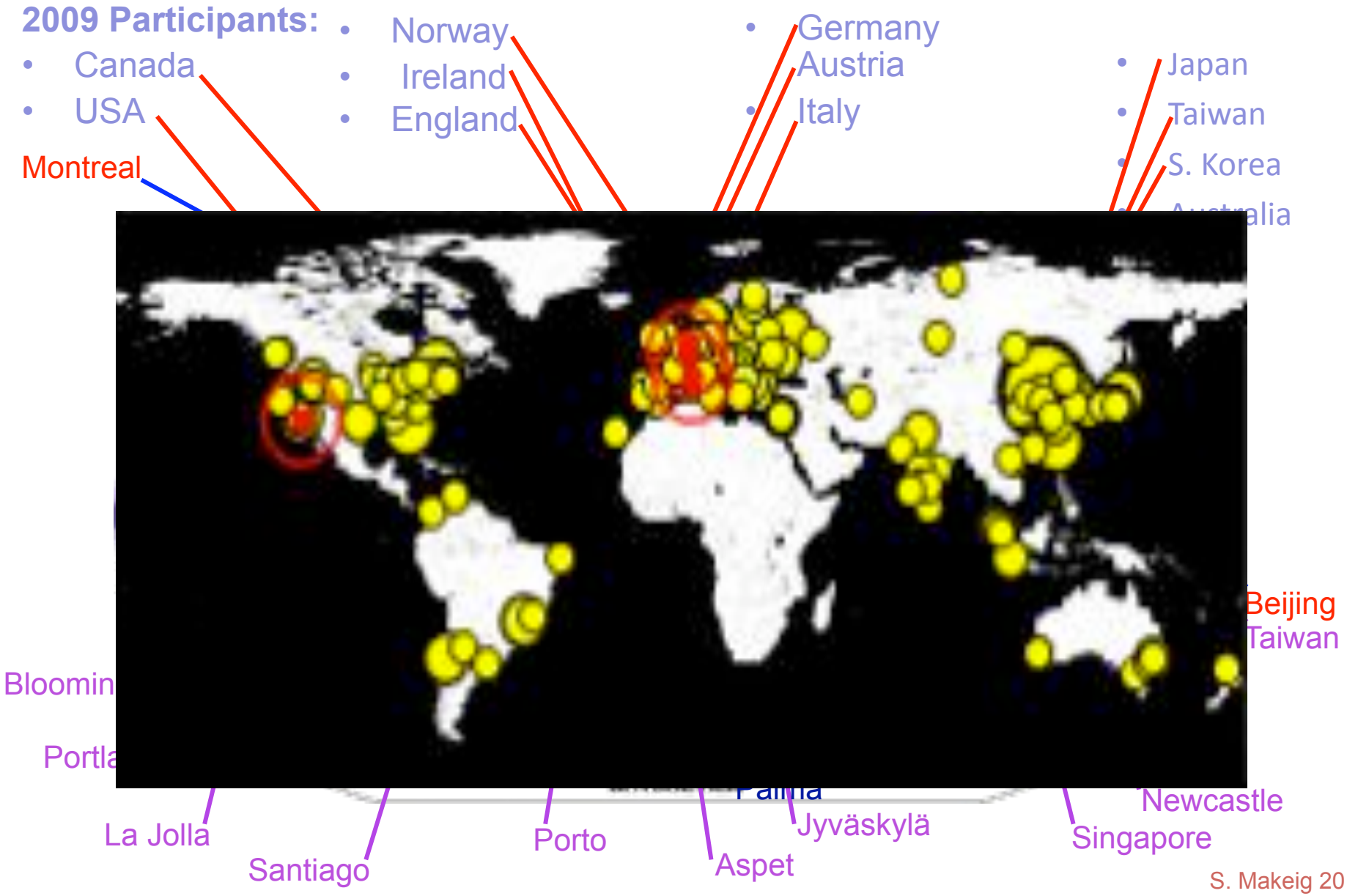
- 200+ EEGLAB downloads a week

  … to at least 90 country domains in all

- >3,500 on the ‘eeglablist’ discussion list
- 30+ EEGLAB plug-ins available

S. Makeig 2007

EEGLAB Workshops



Arnaud Delorme

Swartz Center for Computational Neuroscience

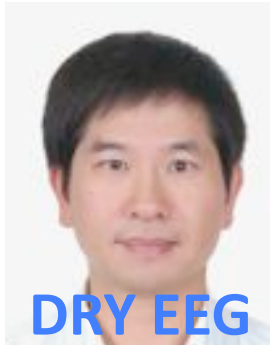
Christian Kothe

David Groppe

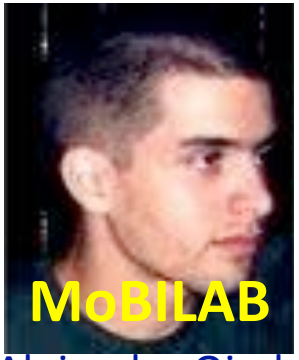
Jason Palmer

Julie Onton

Tim Mullen



Tzyy-Ping Jung



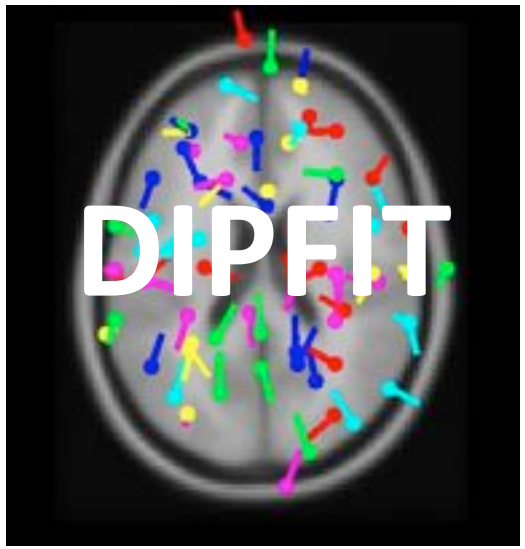
Alejandro Ojeda

Tony Bell

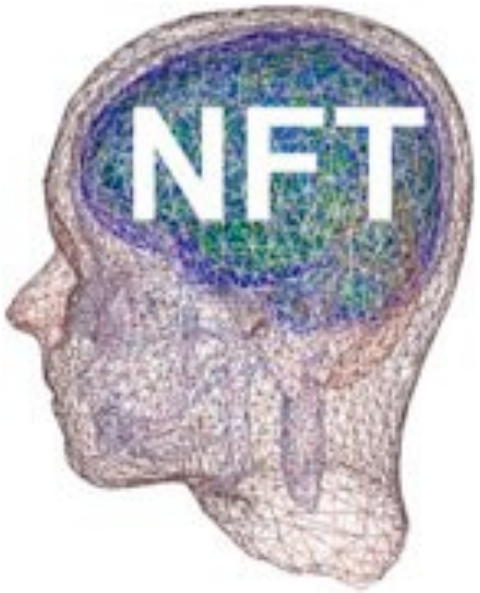
Zeynep Akalin Acar

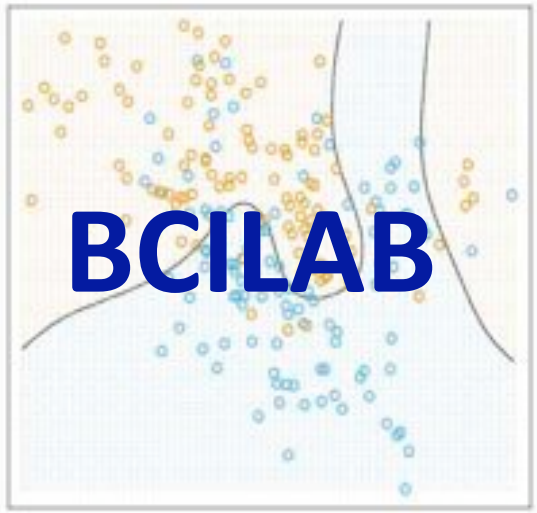
Nima Bigdely Shamlo

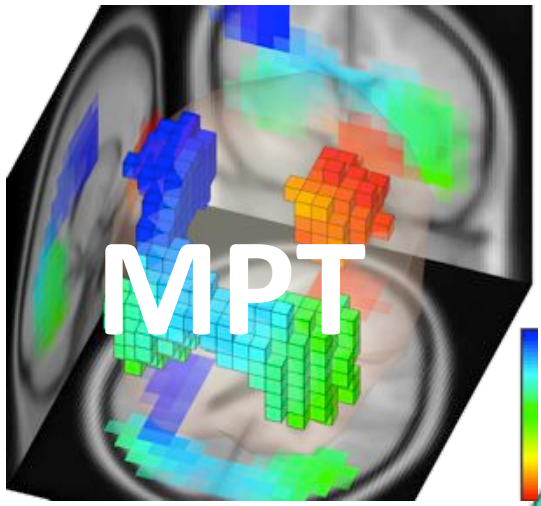
S. Makeig (2011)

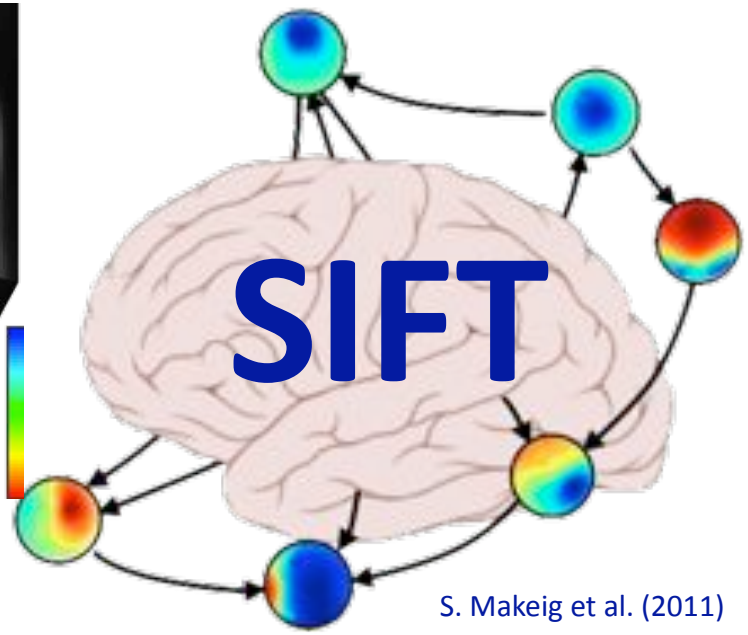


EEGLAB Toolboxes

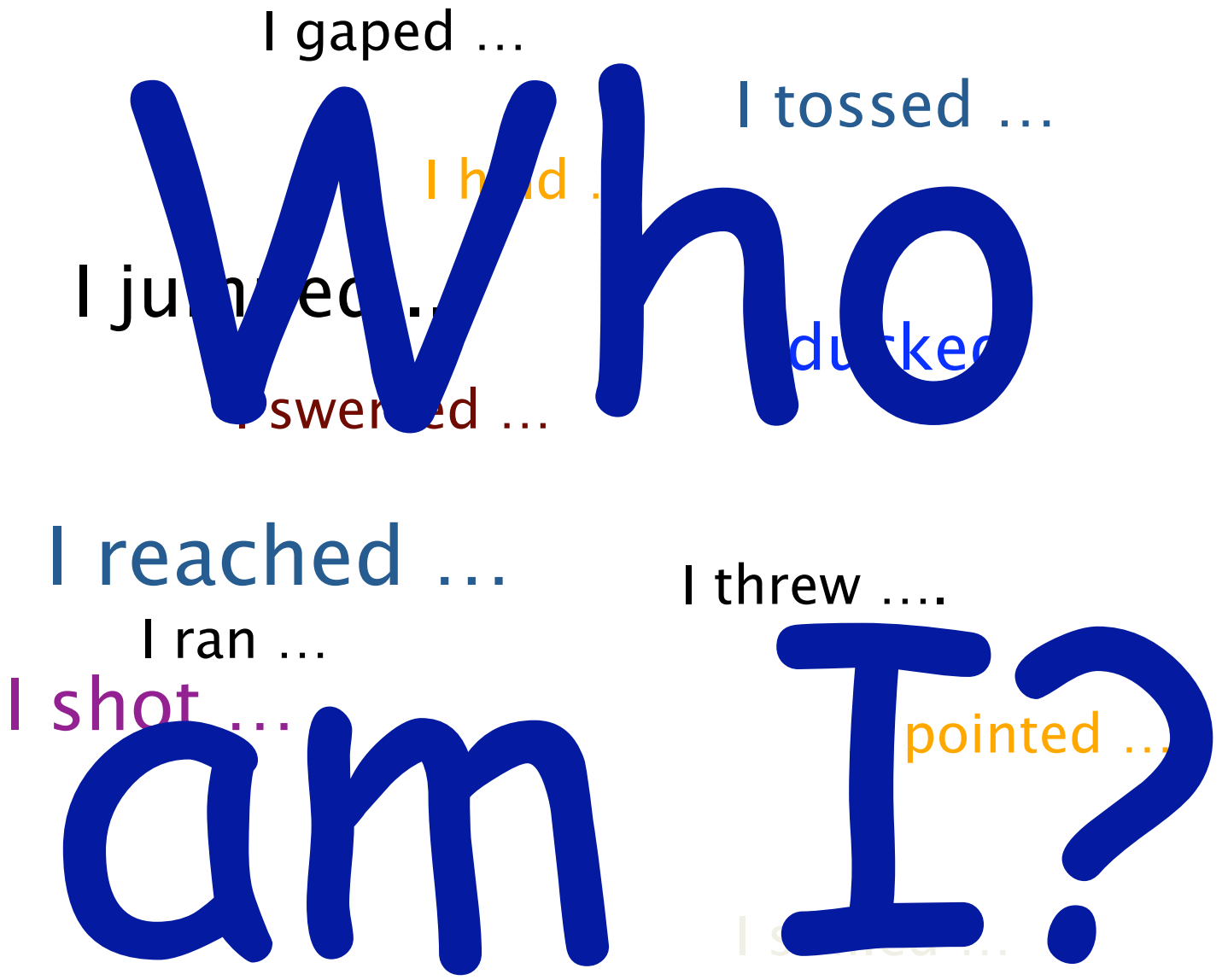




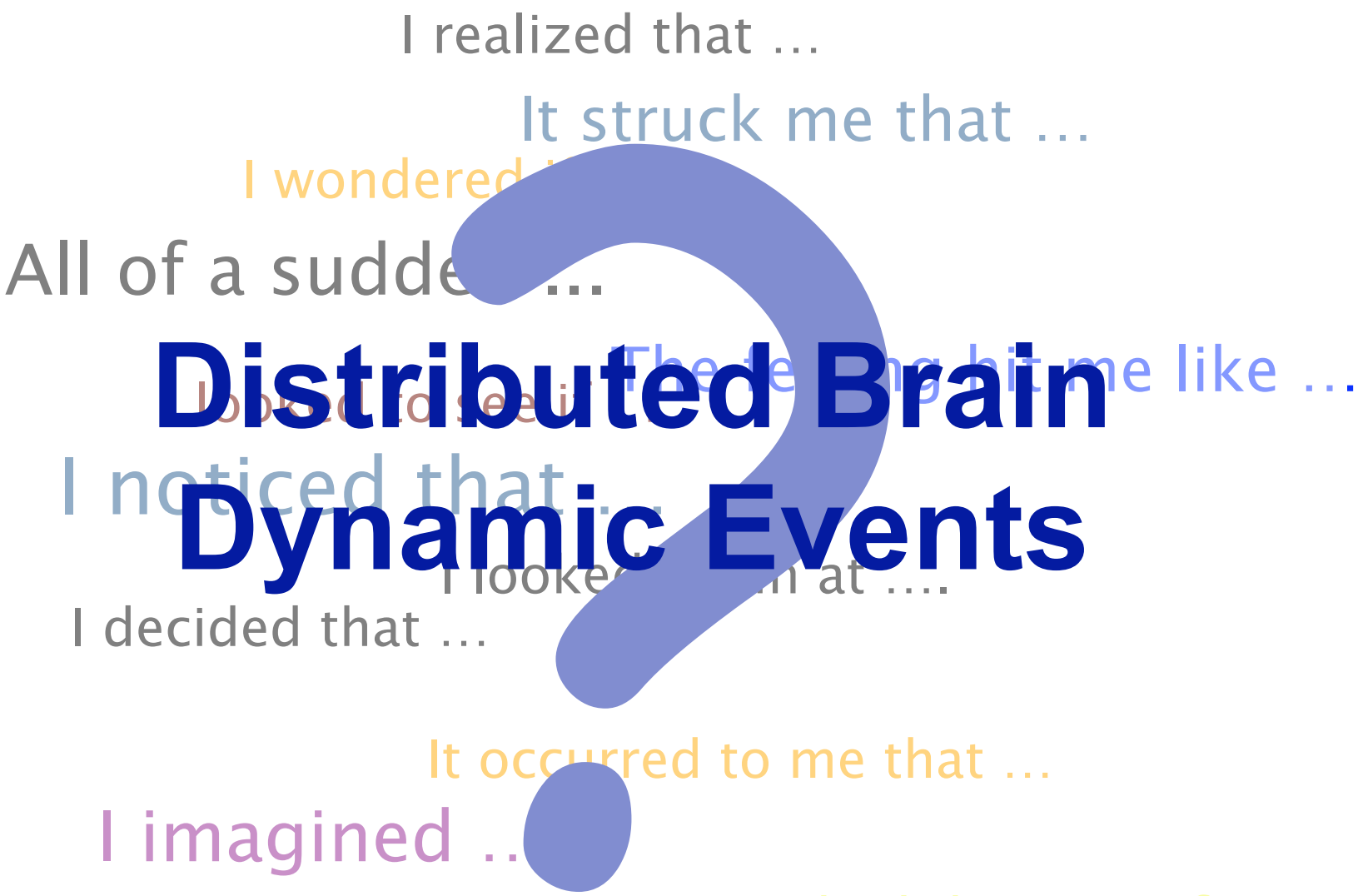




S. Makeig et al. (2011)



S. Makeig 2001



S. Makeig 2001

I realized that …

It struck me that …

I wondered if …

All of a sudden ...

The feeling hit me like …

I looked to see if …

I noticed that …

I thought again ….

I decided that …

It occurred to me that …

I imagined …

I searched my memory for …

S. Makeig 2001

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 …

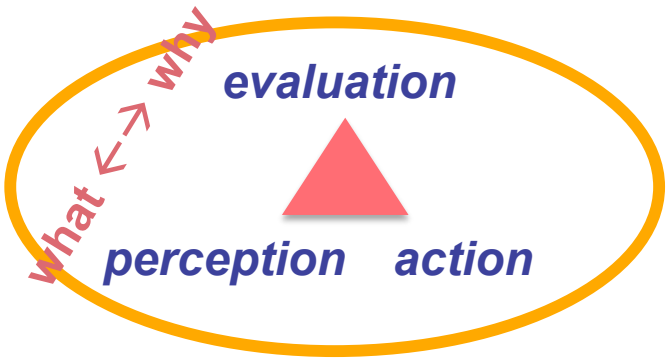
I froze, eyes open wide …

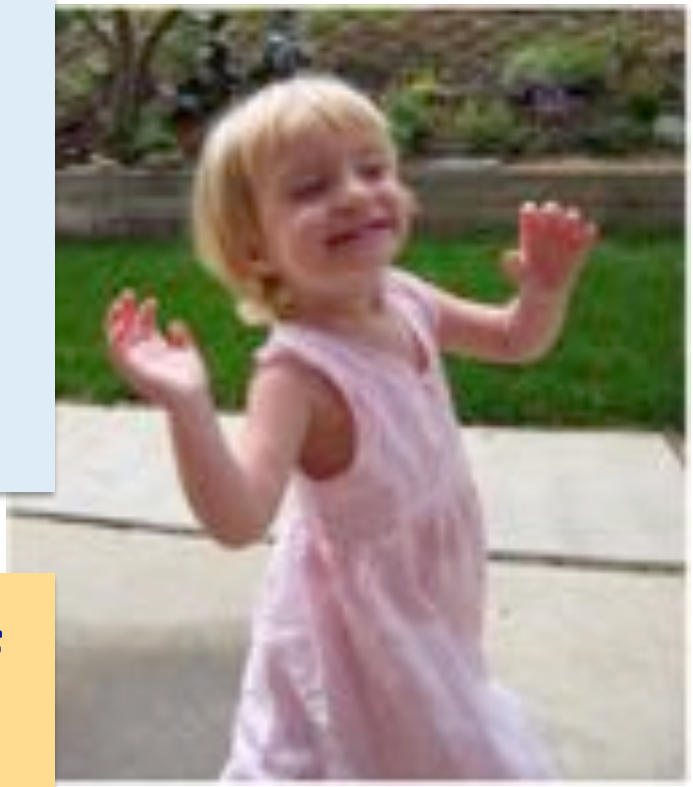
I breathed in slowly and …

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.





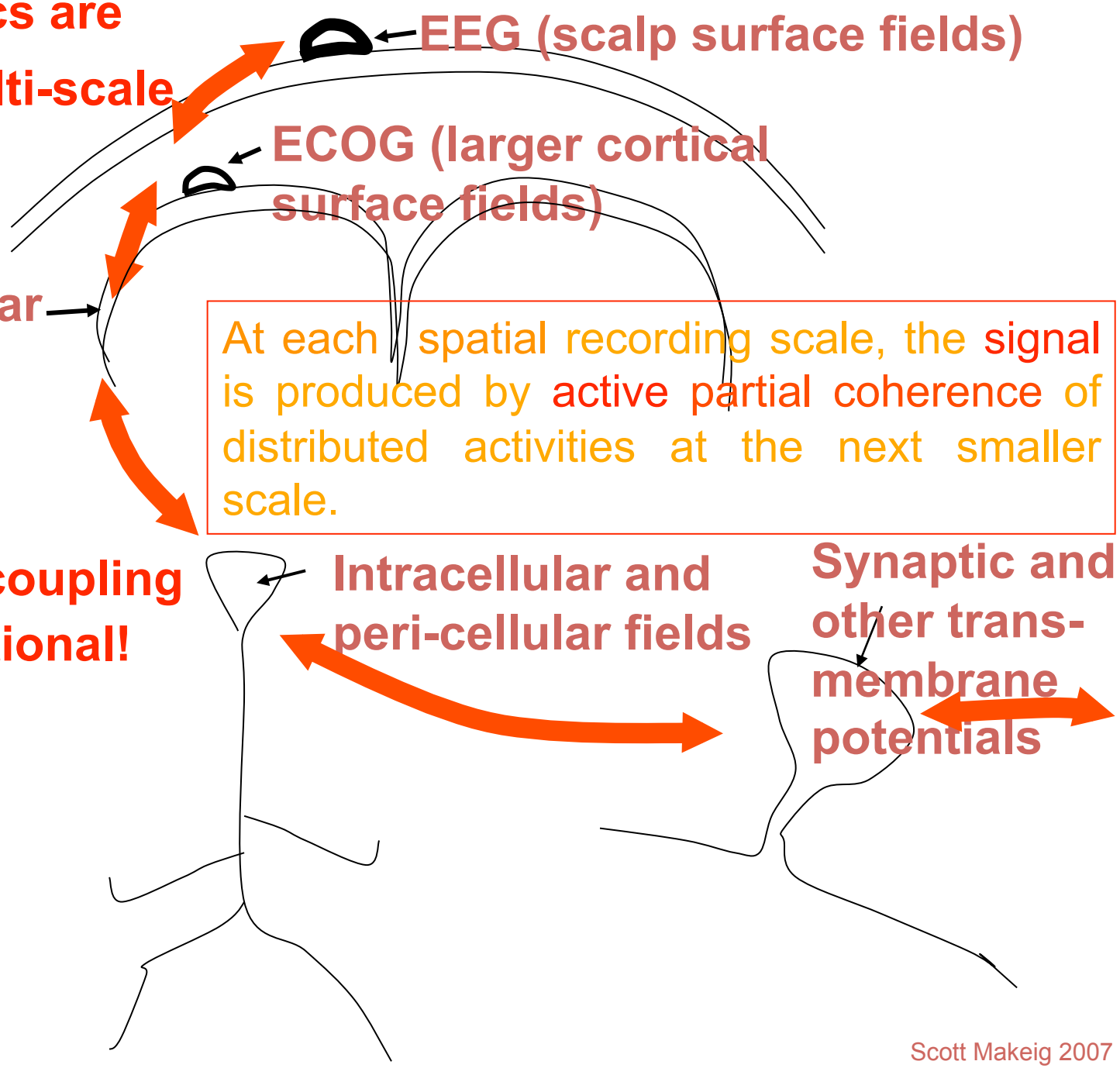
Brains meet the challenge of the moment!

S. Makeig 2011

What is EEG?

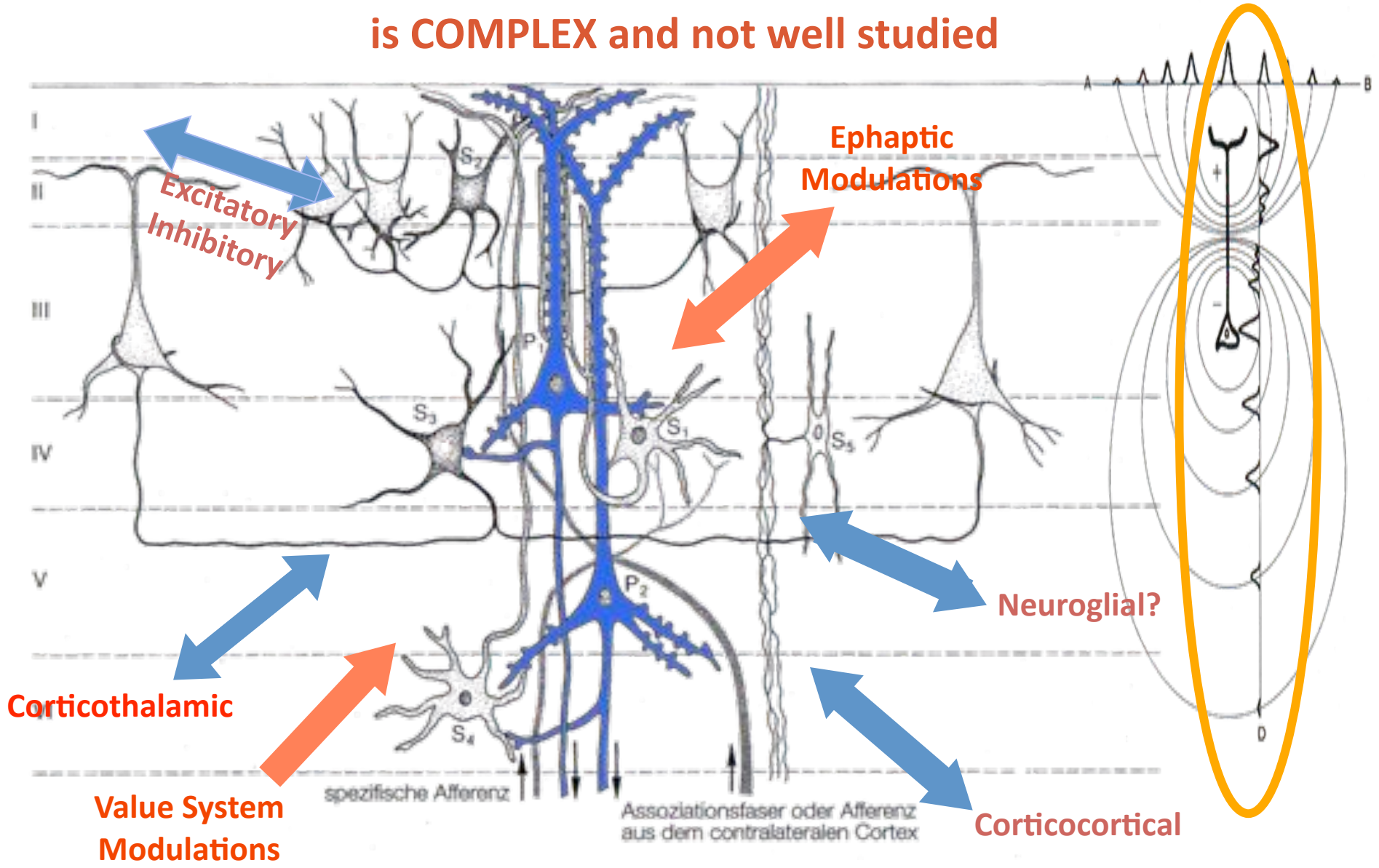
Makeig (2006)

Brain dynamics are inherently multi-scale



Scott Makeig 2007

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



S. Makeig 2007

Functional Brain Imaging

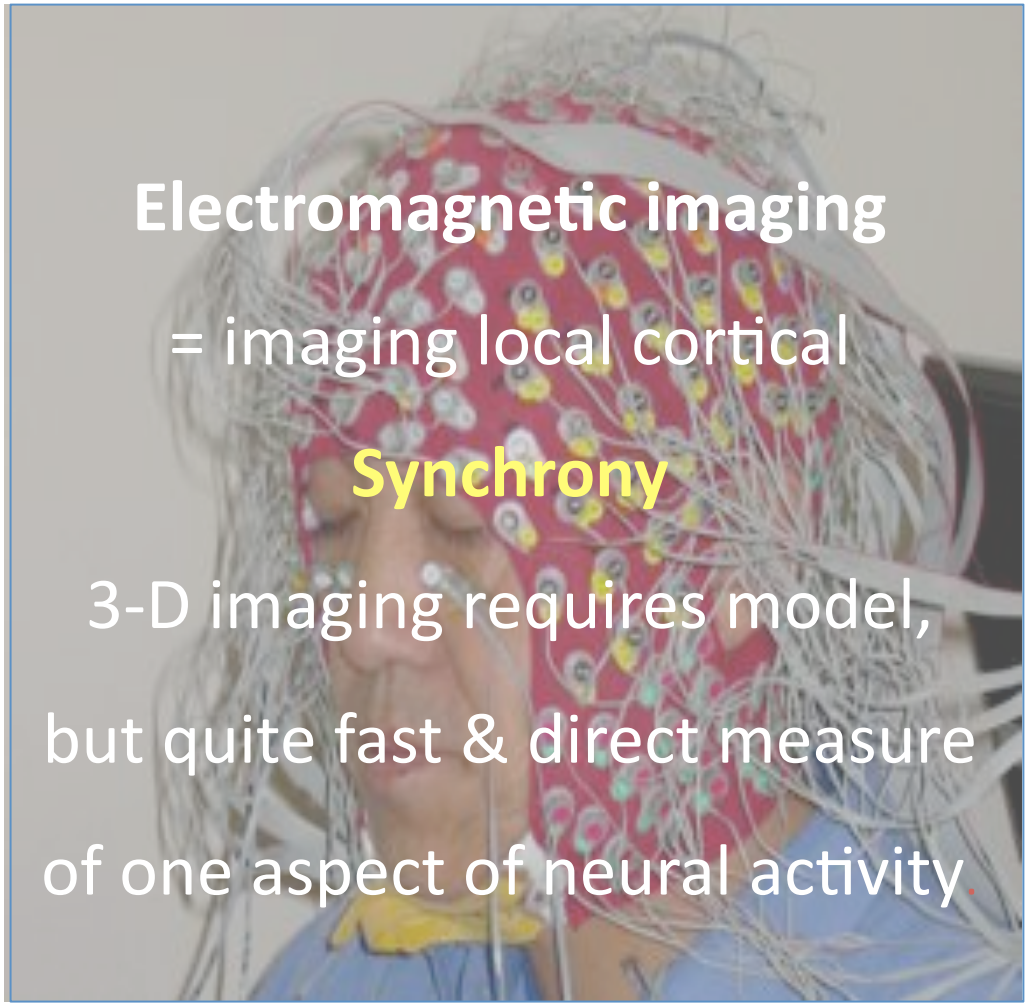
Hemodynamic imaging

= 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

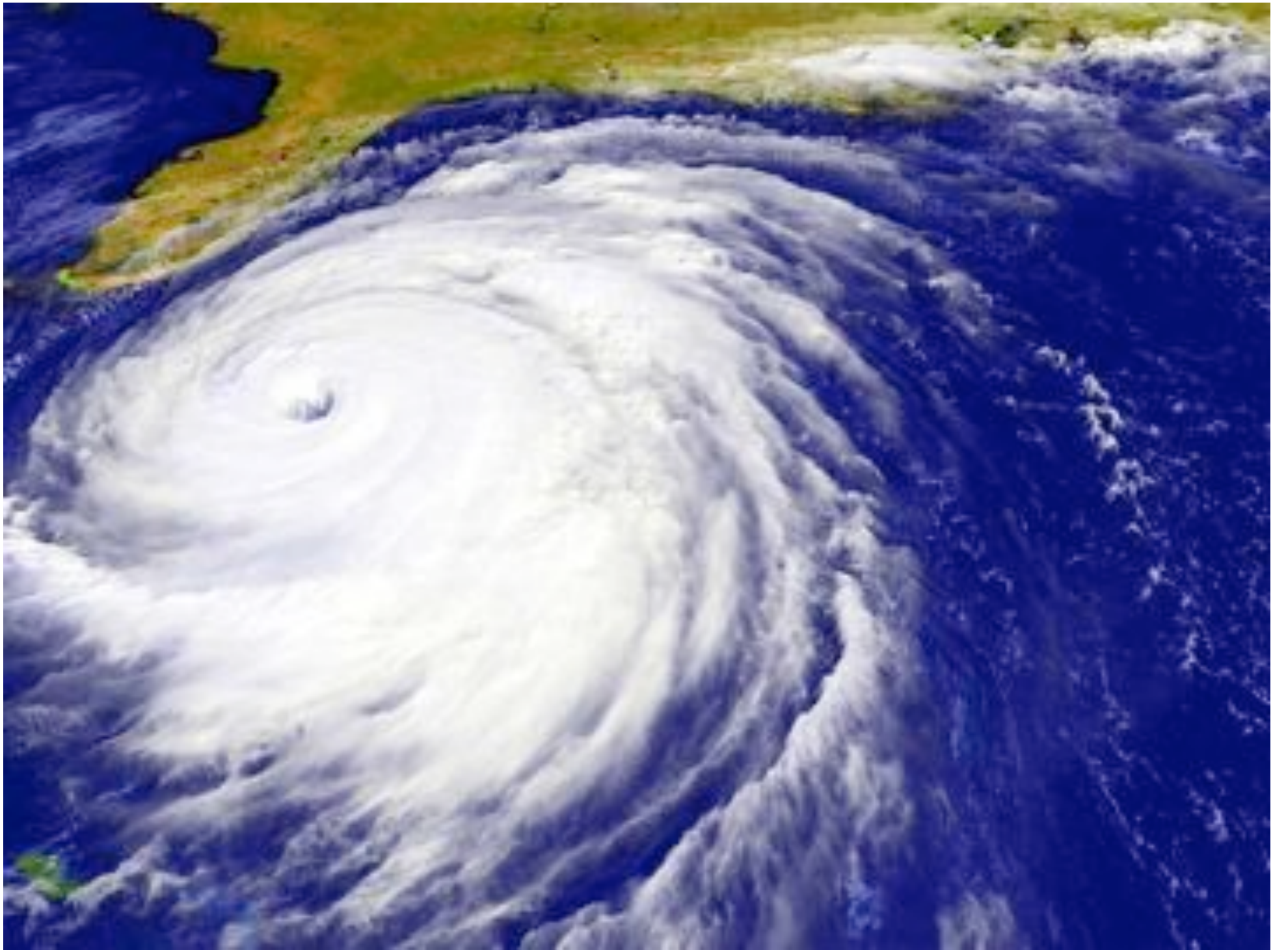
of one aspect of neural activity.

S. Makeig 2010

Phase cones (Freeman)

Avalanches (Plenz)

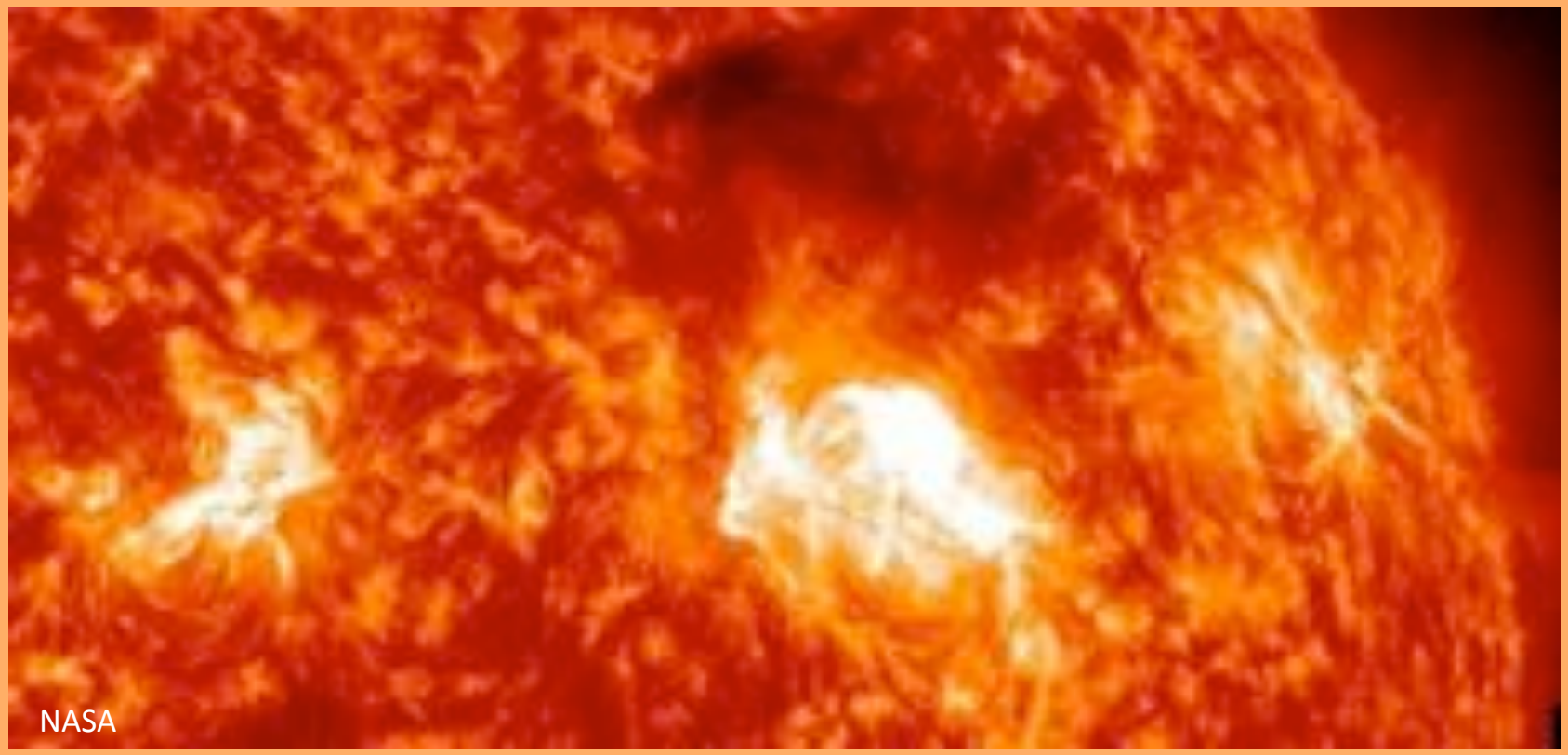
S. Makeig 2010



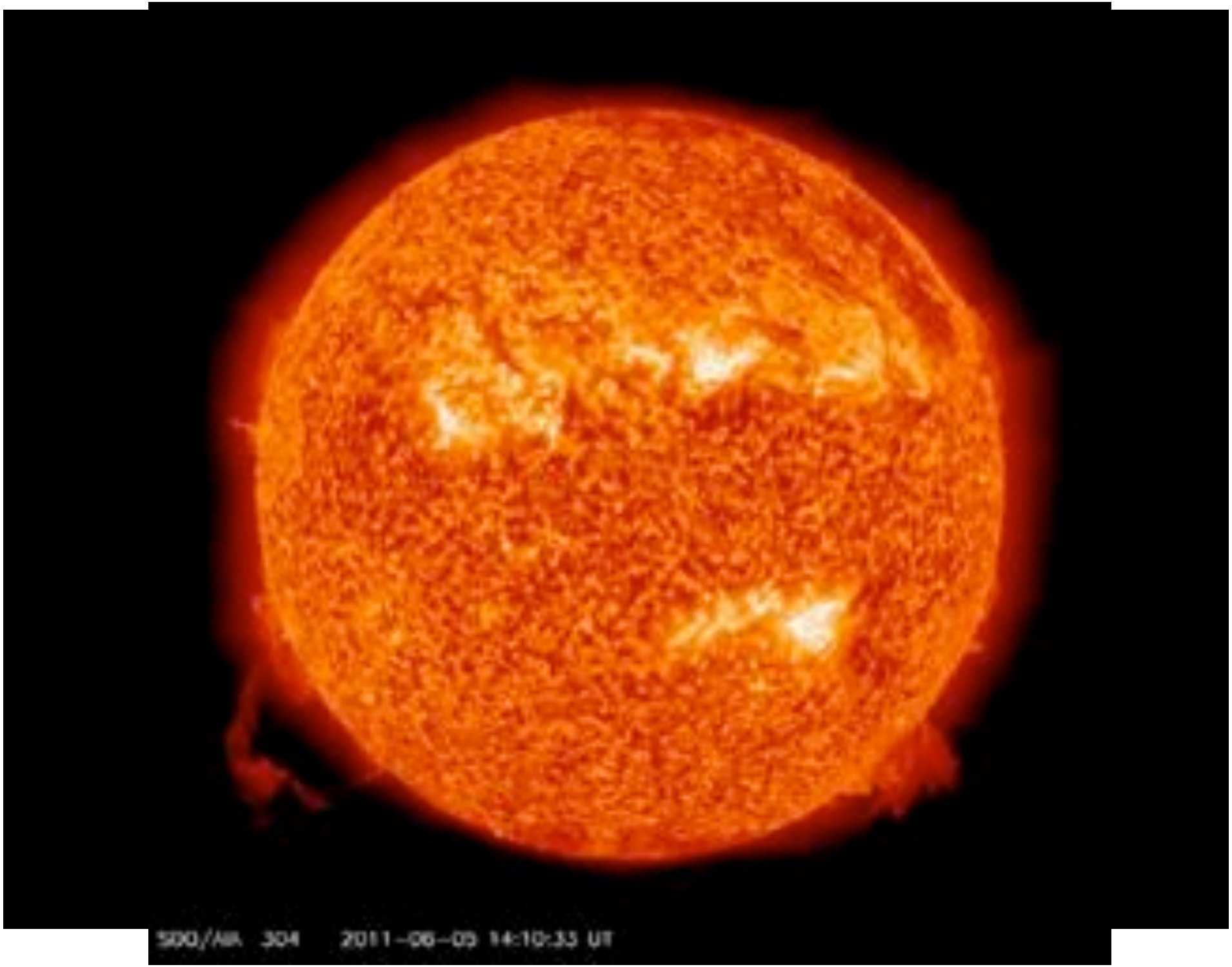

Macro field dynamics are spontaneous emergent dynamic patterns – in both space and cortex.
Scott Makeig 2008

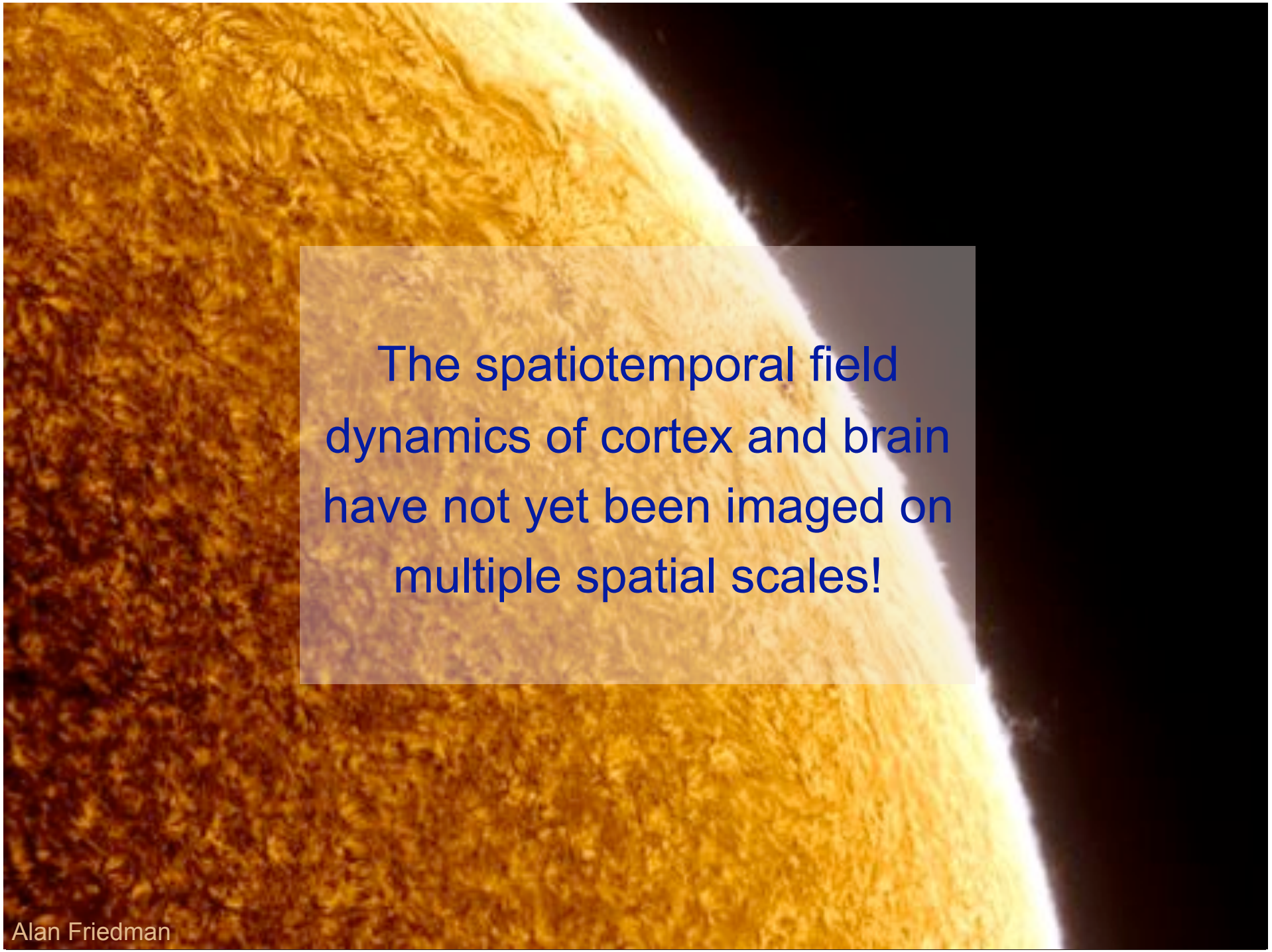
Alan Friedman

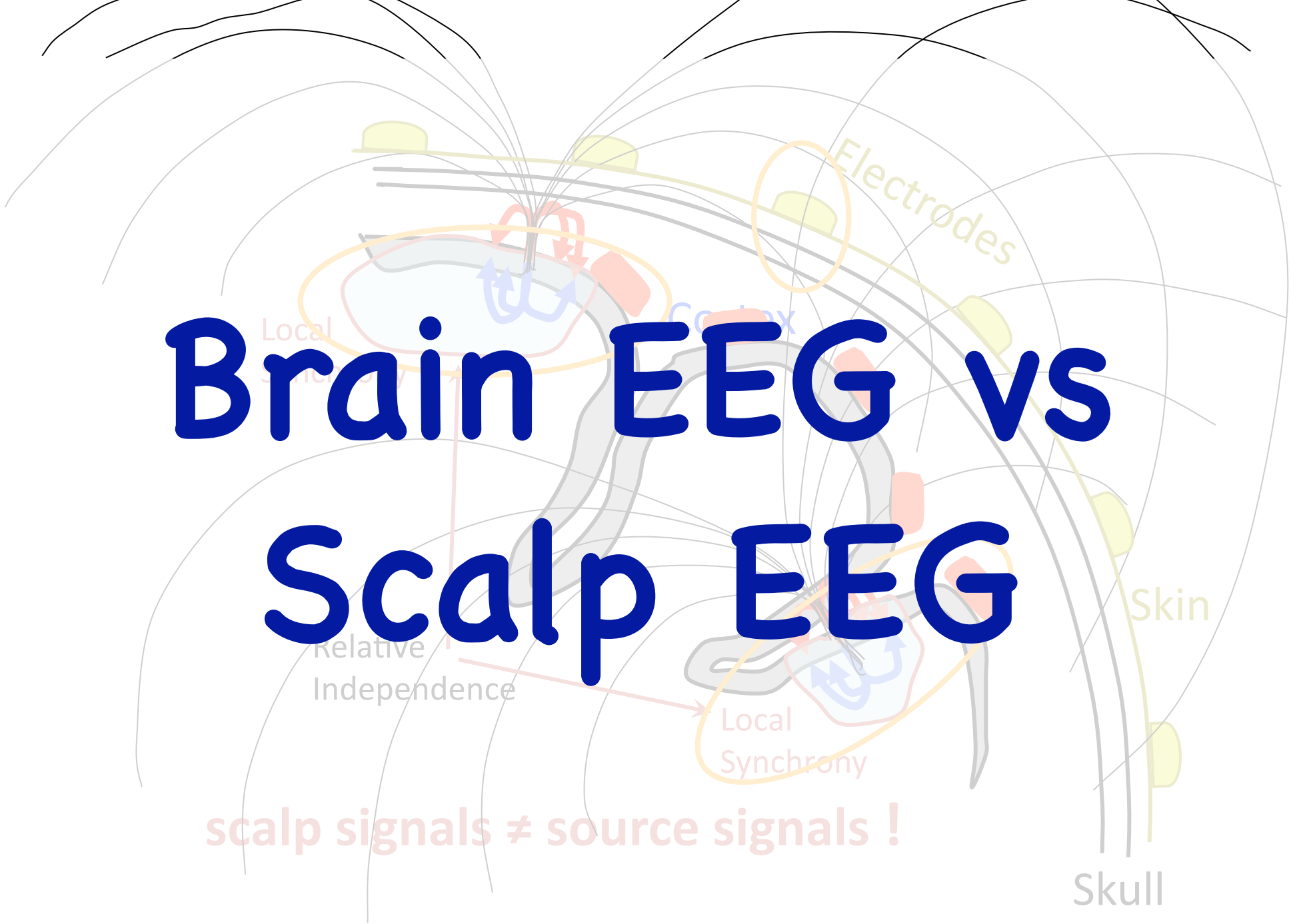
EEG Sources are emergent cortical domains of local field synchrony



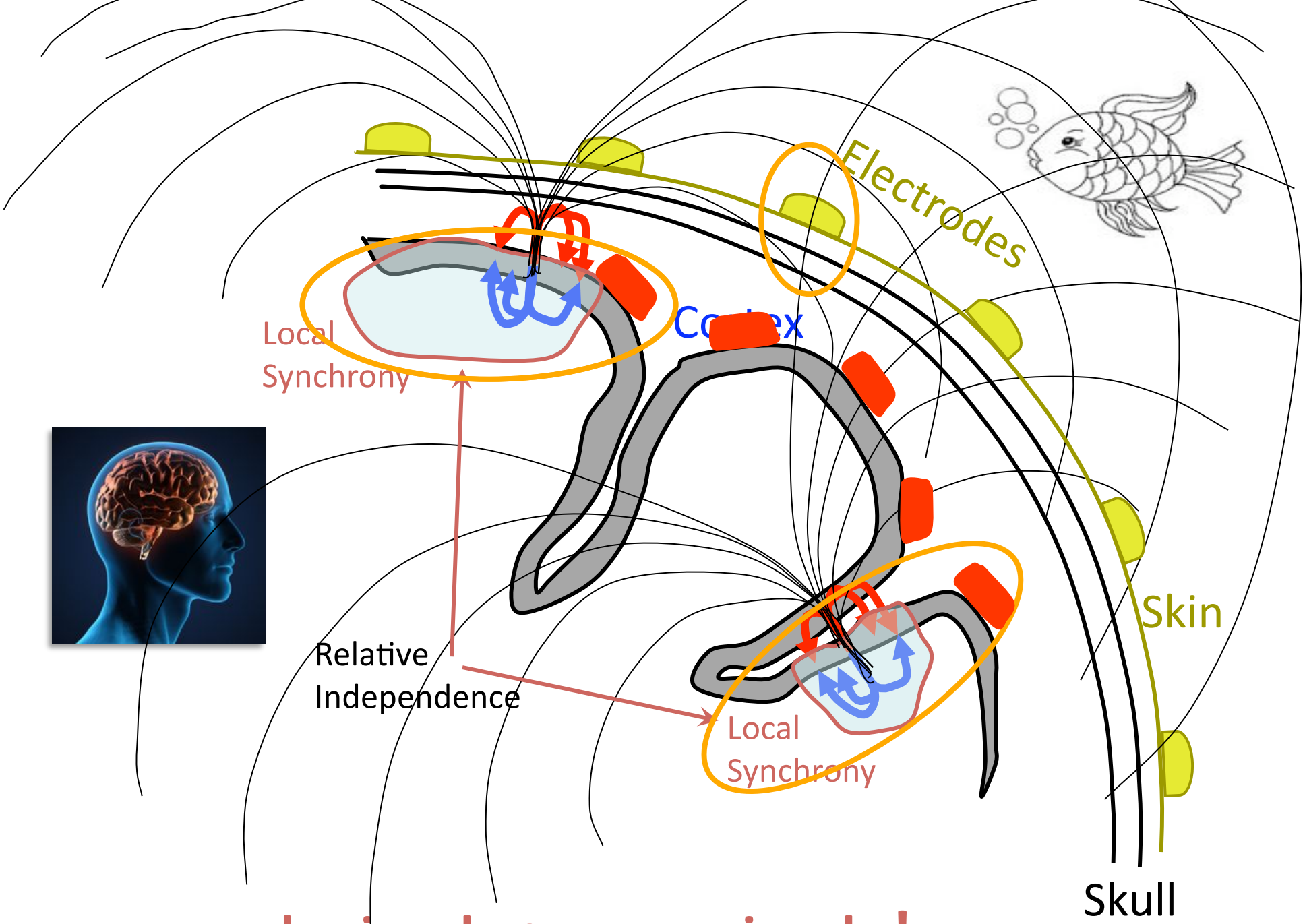
S Makeig, 2011


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!
Alan Friedman



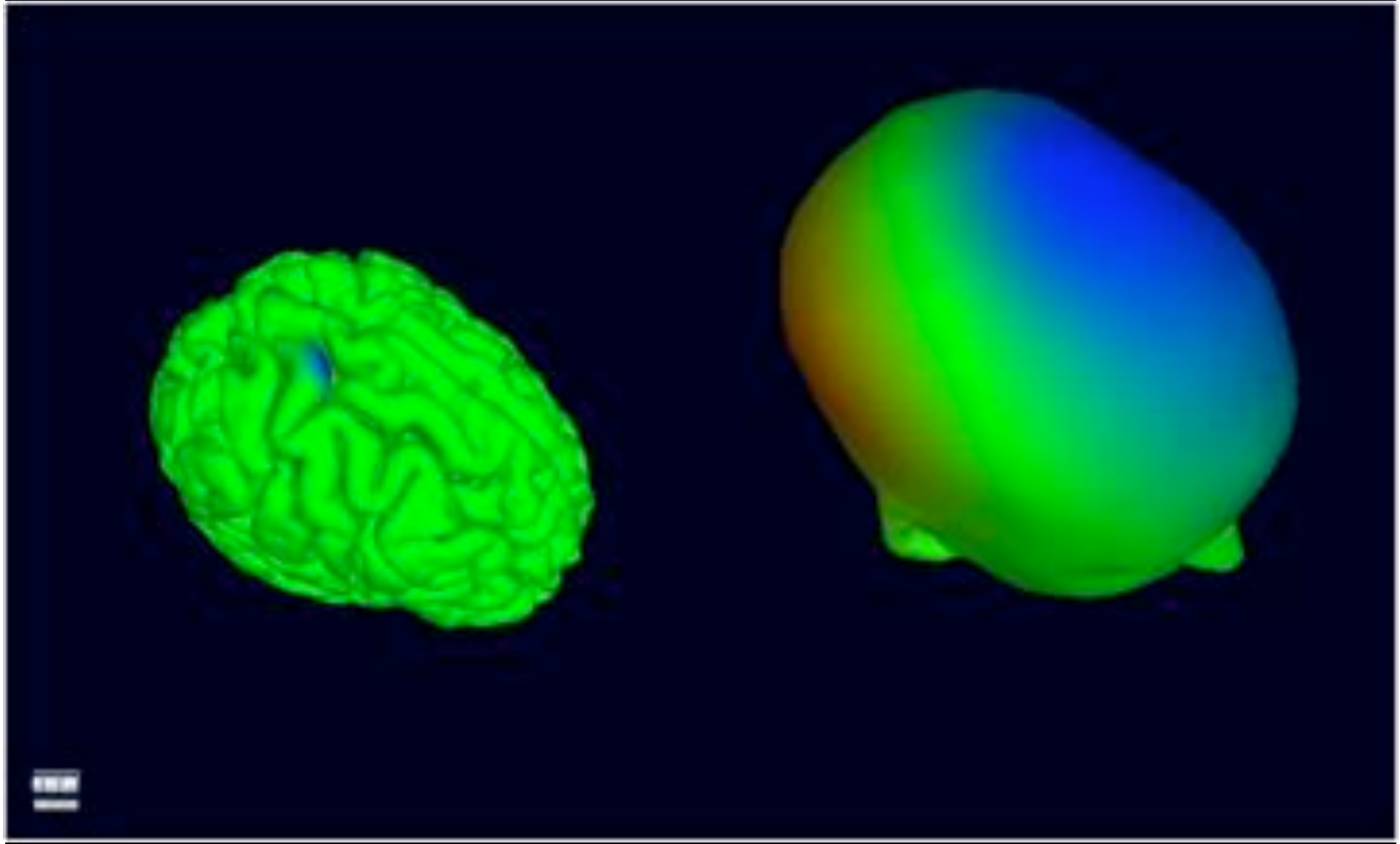
Brain EEG vs Scalp EEG



scalp signals ≠ source signals !

S. Makeig 2007

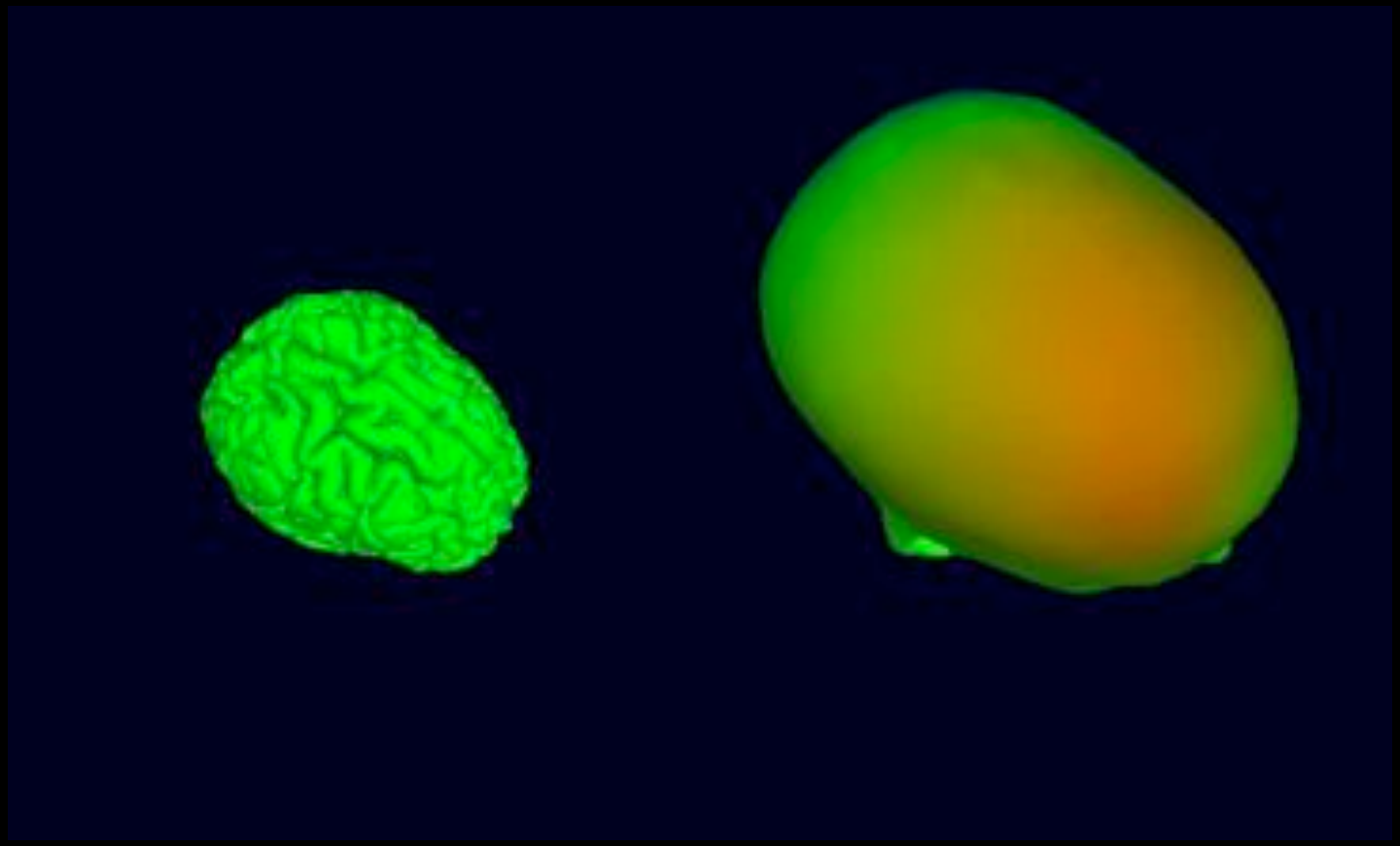
The very broad EEG point-spread function



Single source domain

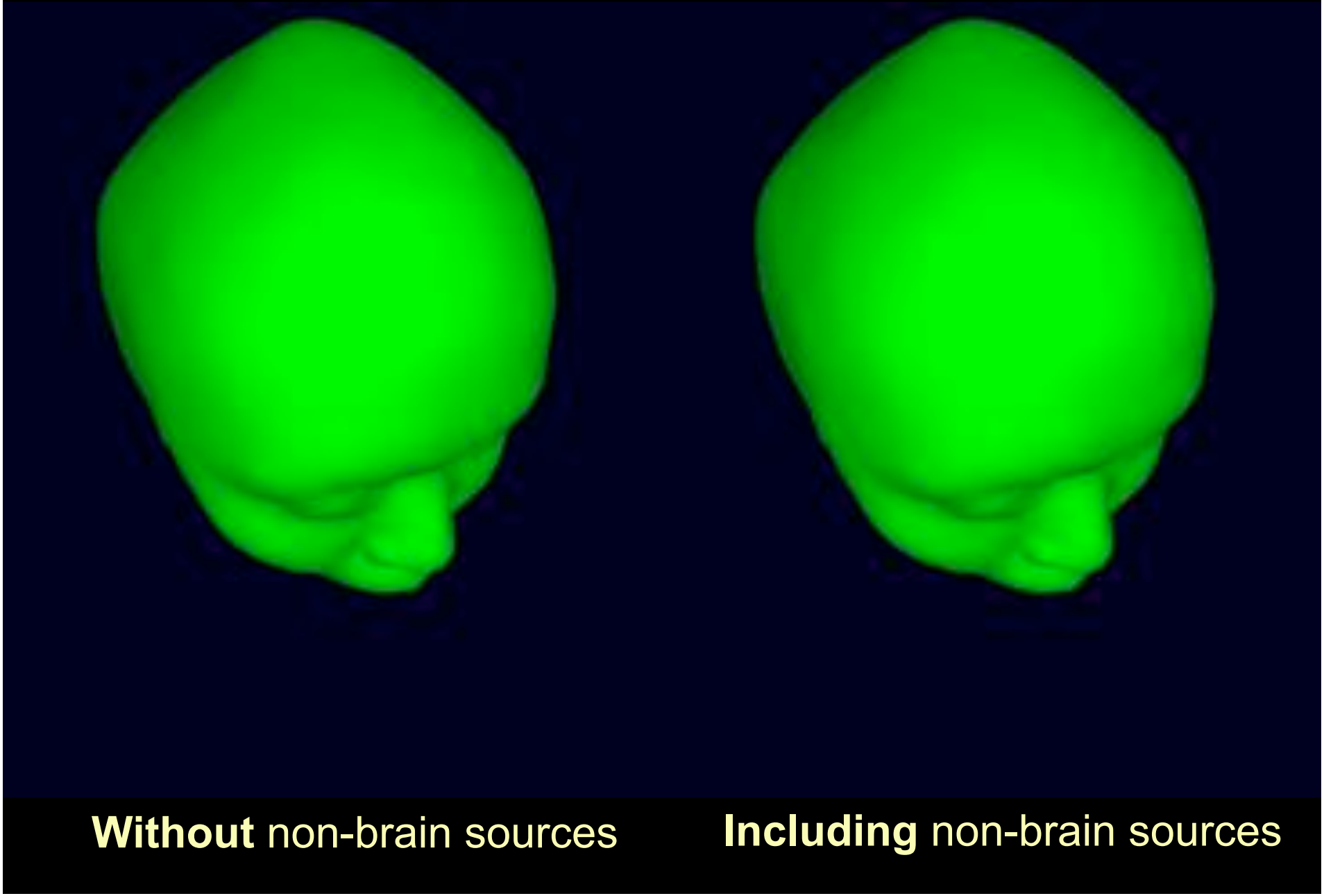
Akalin Acar & Makeig 2010

The very broad EEG point-spread function



Z. Akalin Acar & S. Makeig 2010

Effects of non-brain artifacts on scalp EEG

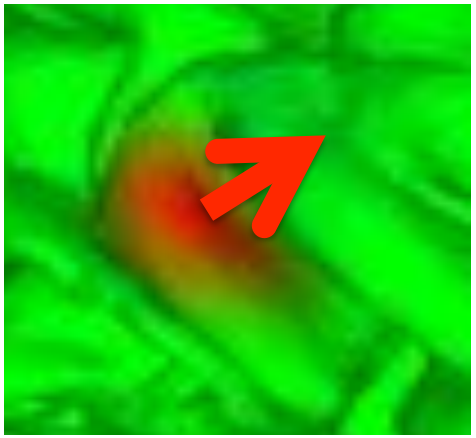


Without non-brain sources

Including non-brain sources

Electromagnetic source localization using realistic head models

Simple Map



Source Estimate

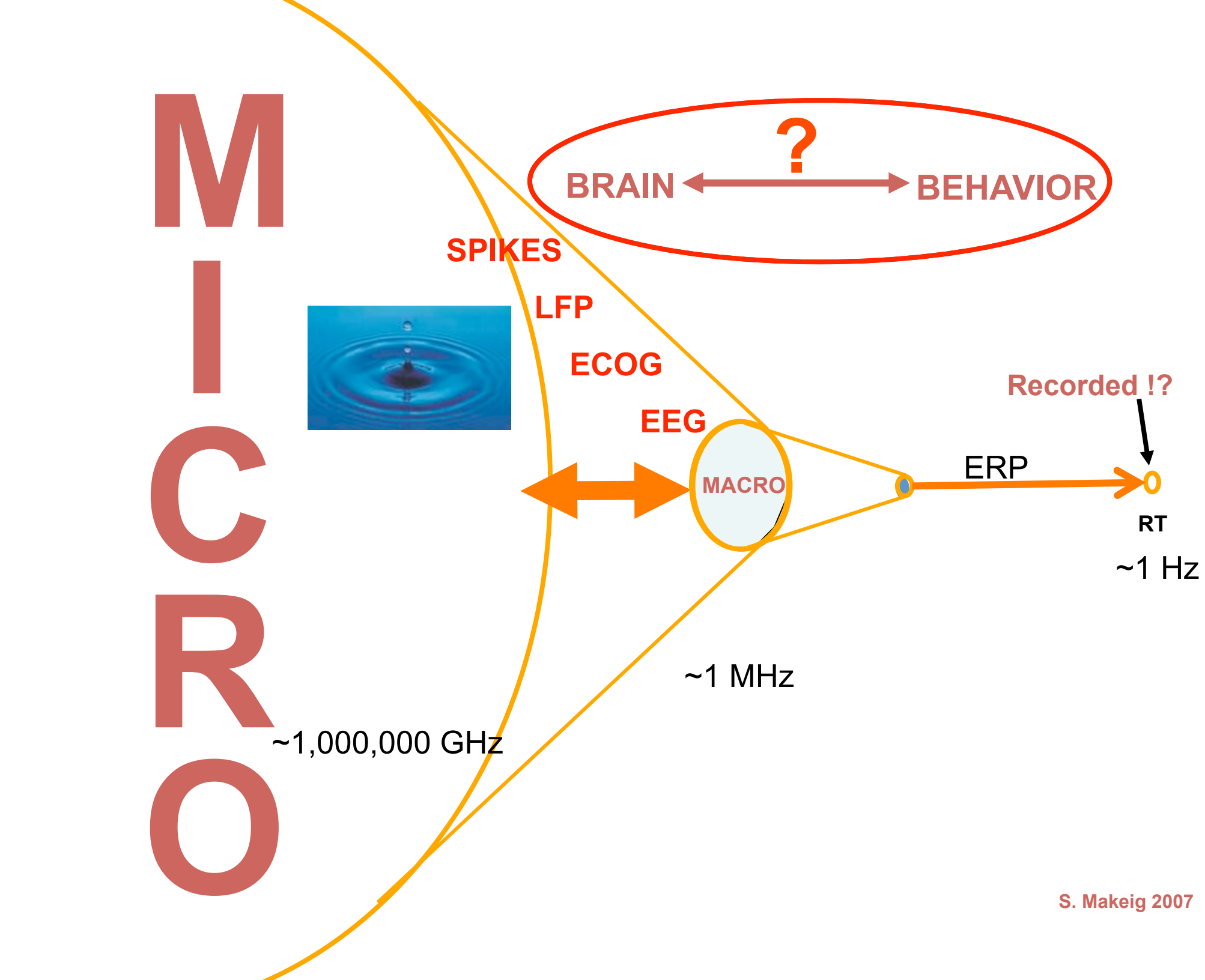
Signal Processing

MRI

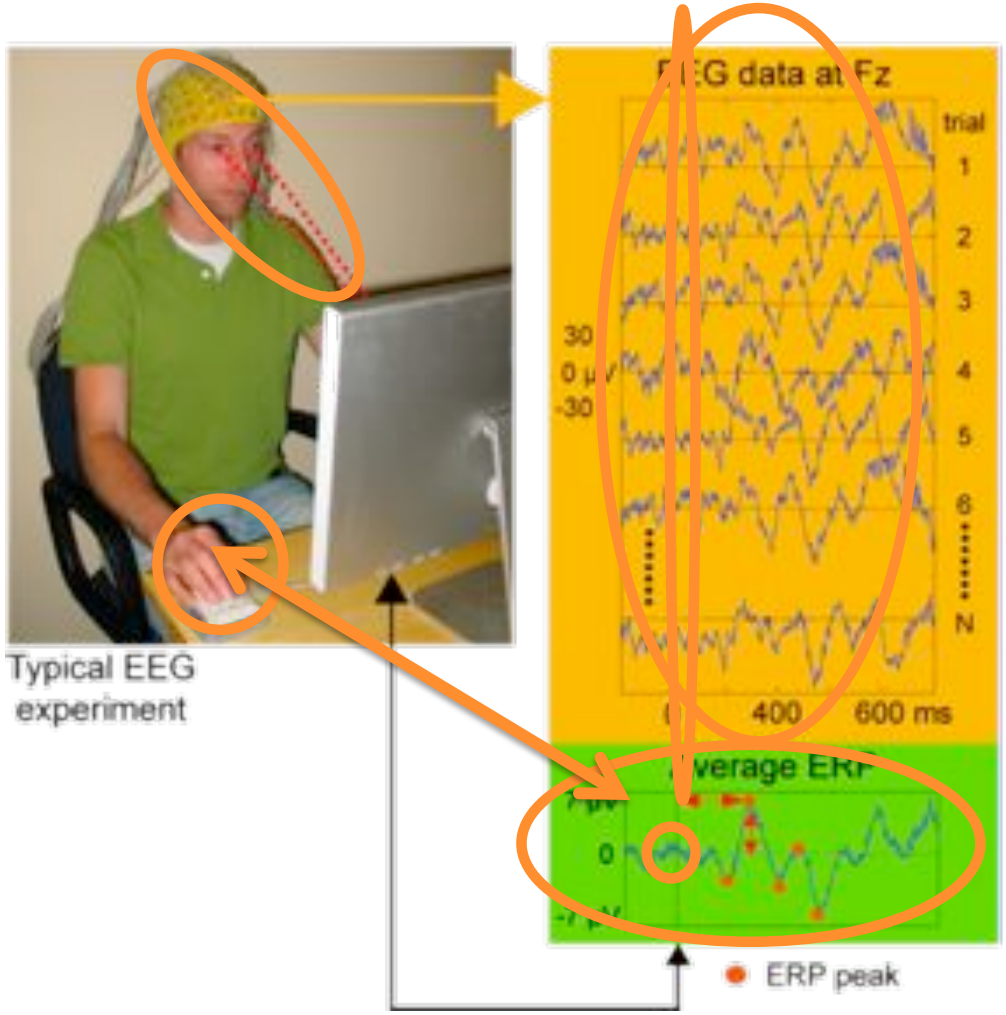
Segmentation

EEG/MEG

Zeynep Akalin Acar & Scott Makeig '06


MICRO
?
BRAIN
BEHAVIOR
SPIKES
LFP
ECOG
EEG
MACRO
Recorded !?
ERP
RT
~1 Hz
~1 MHz
~1,000,000 GHz
S. Makeig 2007

Studying ‘cognitive perception’ using ERPs



Scott Makeig, 2008

Conceptual legacies of single sensor response/rate averaging

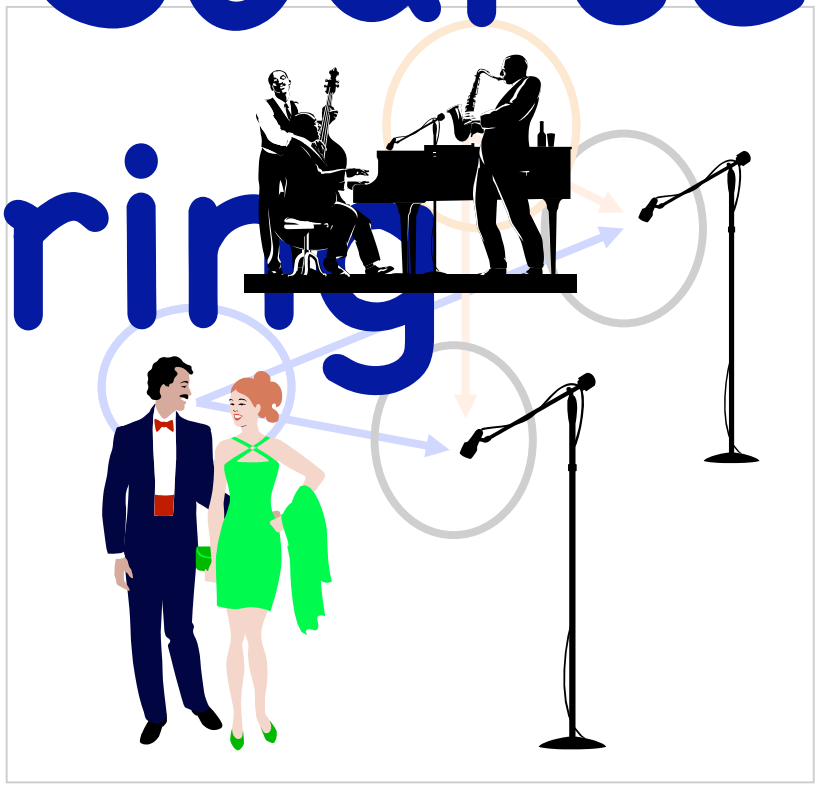
- Reduction of the time series data at each channel to a **single average-response (ERP) time series**.

- 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?

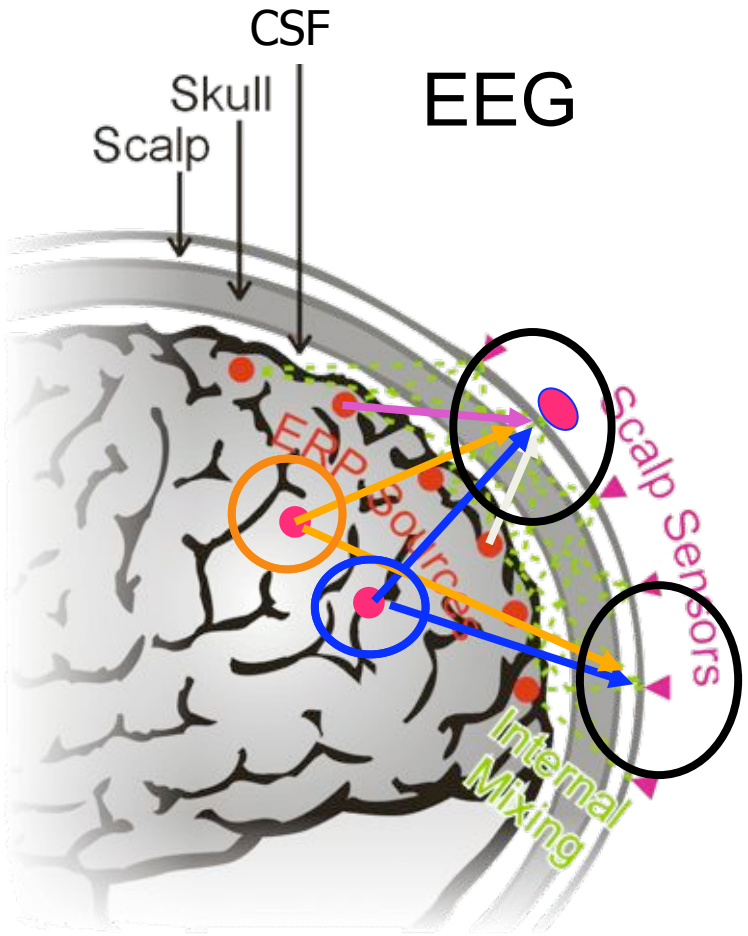
Blind EEG Source Separation by
Independent Component Analysis

Spatial Source Filtering



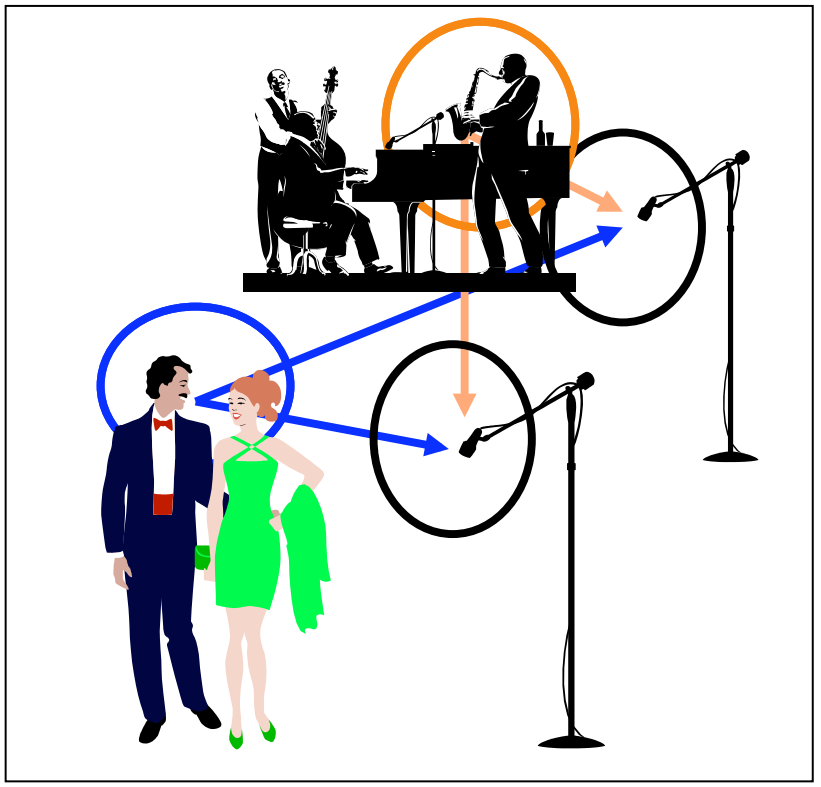
S. Makeig (2000)

Blind EEG Source Separation by Independent Component Analysis



EEG

Cocktail Party



S. Makeig (2000)

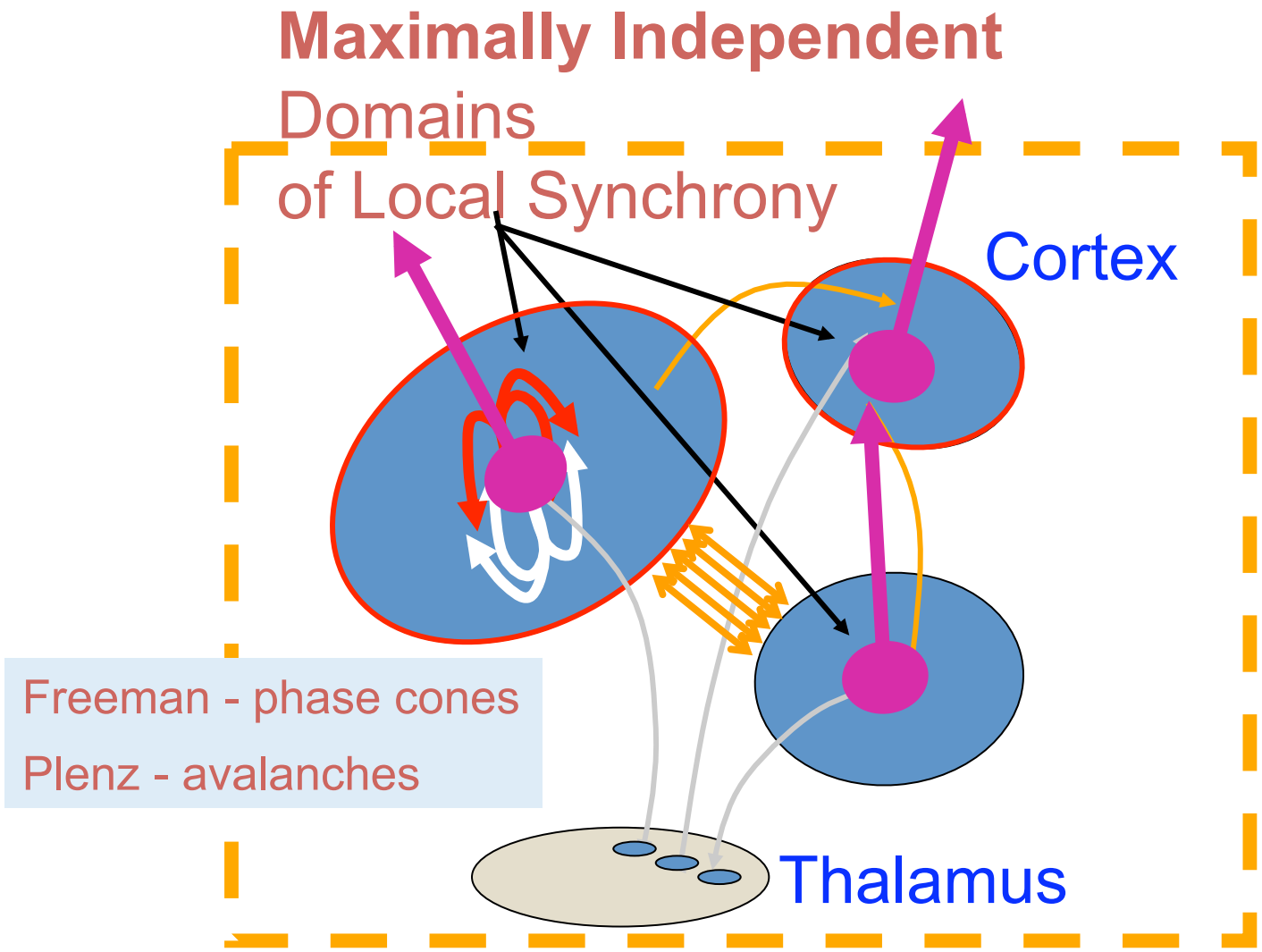
Independent Component Analysis of Electroencephalographic Data

Abstract

Infomax ICA

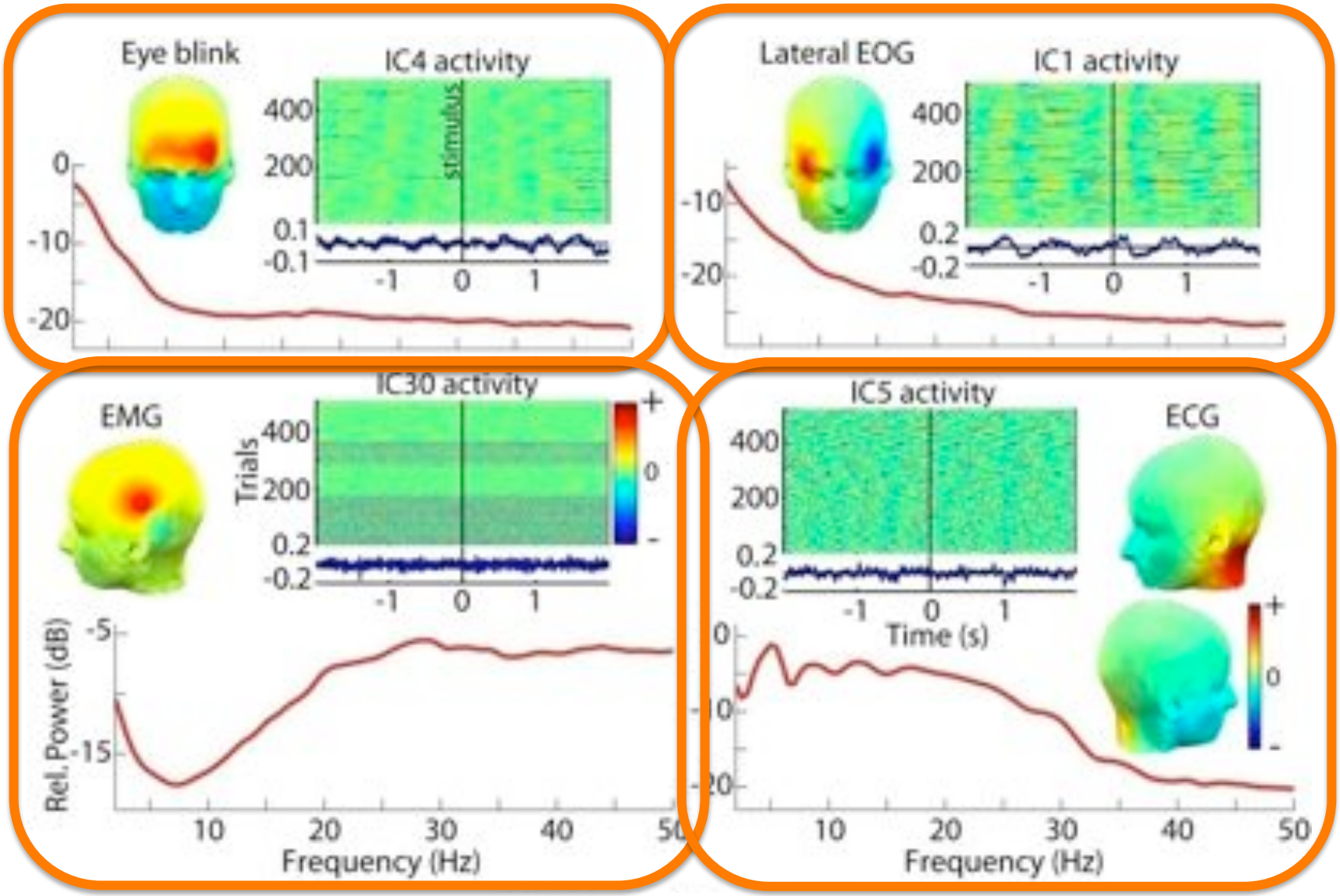
Makeig et al., NIPS95

Are EEG source outputs (nearly) independent?



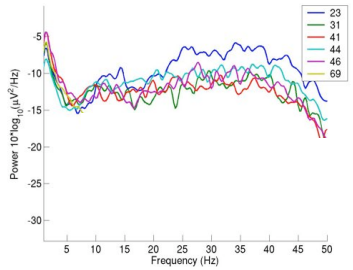
S. Makeig (2007)

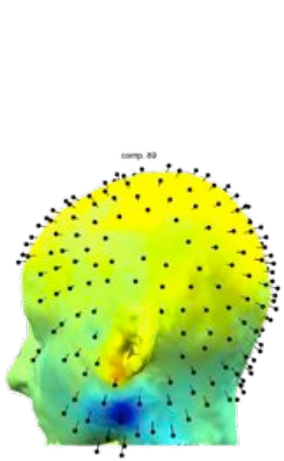
Some non-brain source ICs

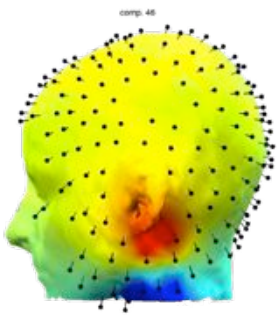


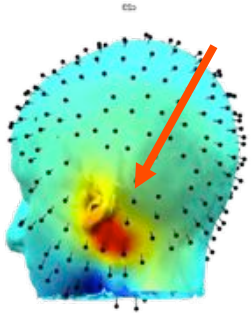
Onton & Makeig, 2006

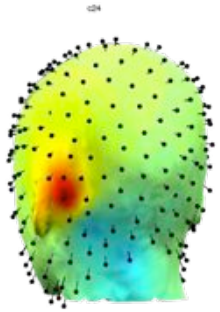
Independent muscle signals

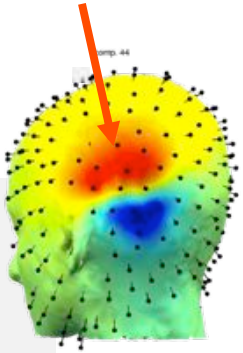


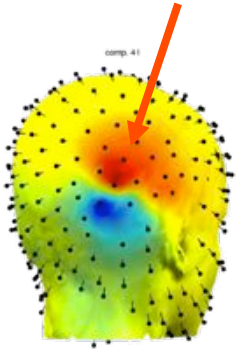


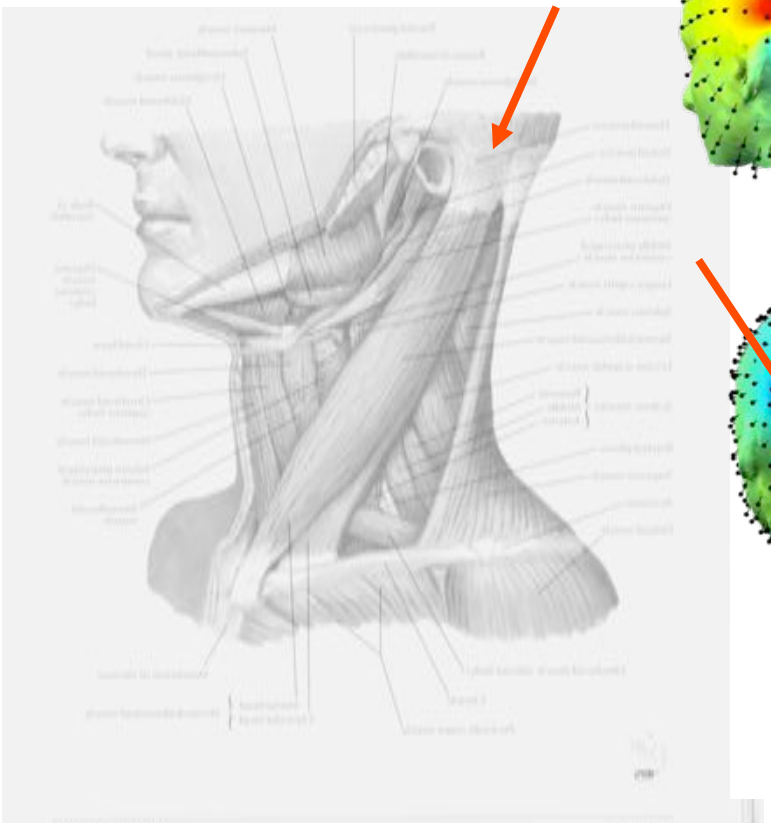


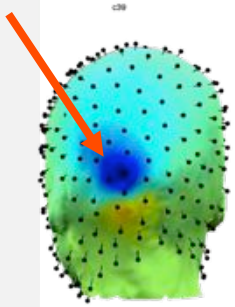


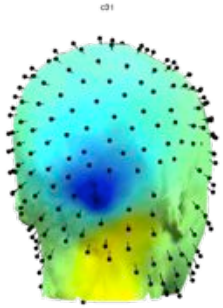


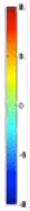


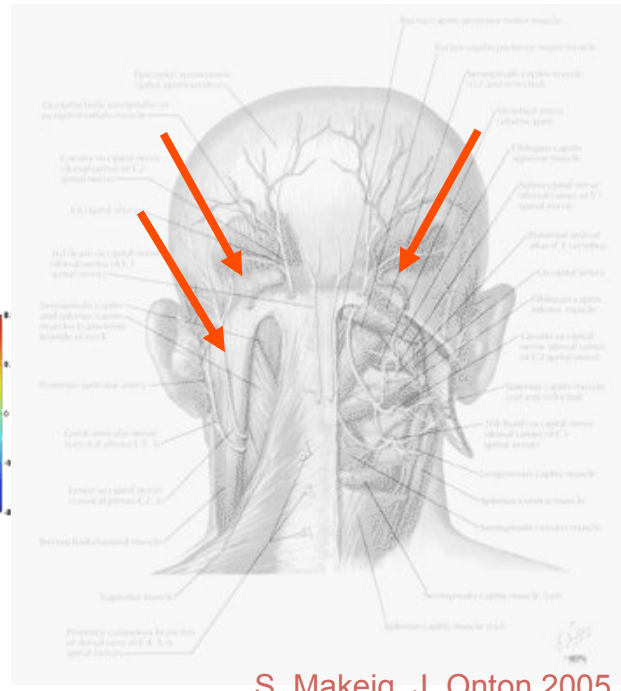






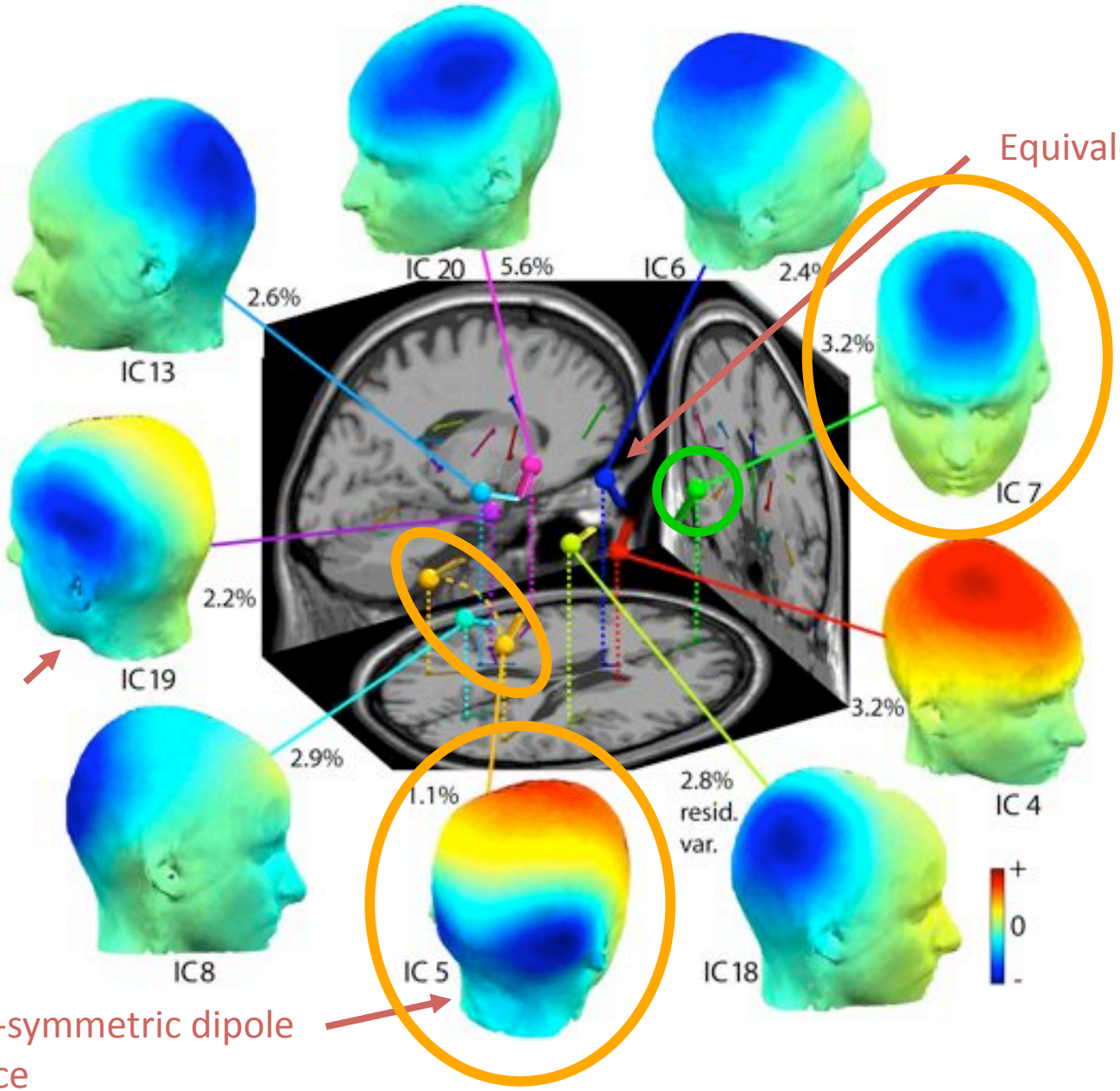






S. Makeig, J. Onton 2005

Independent brain EEG sources



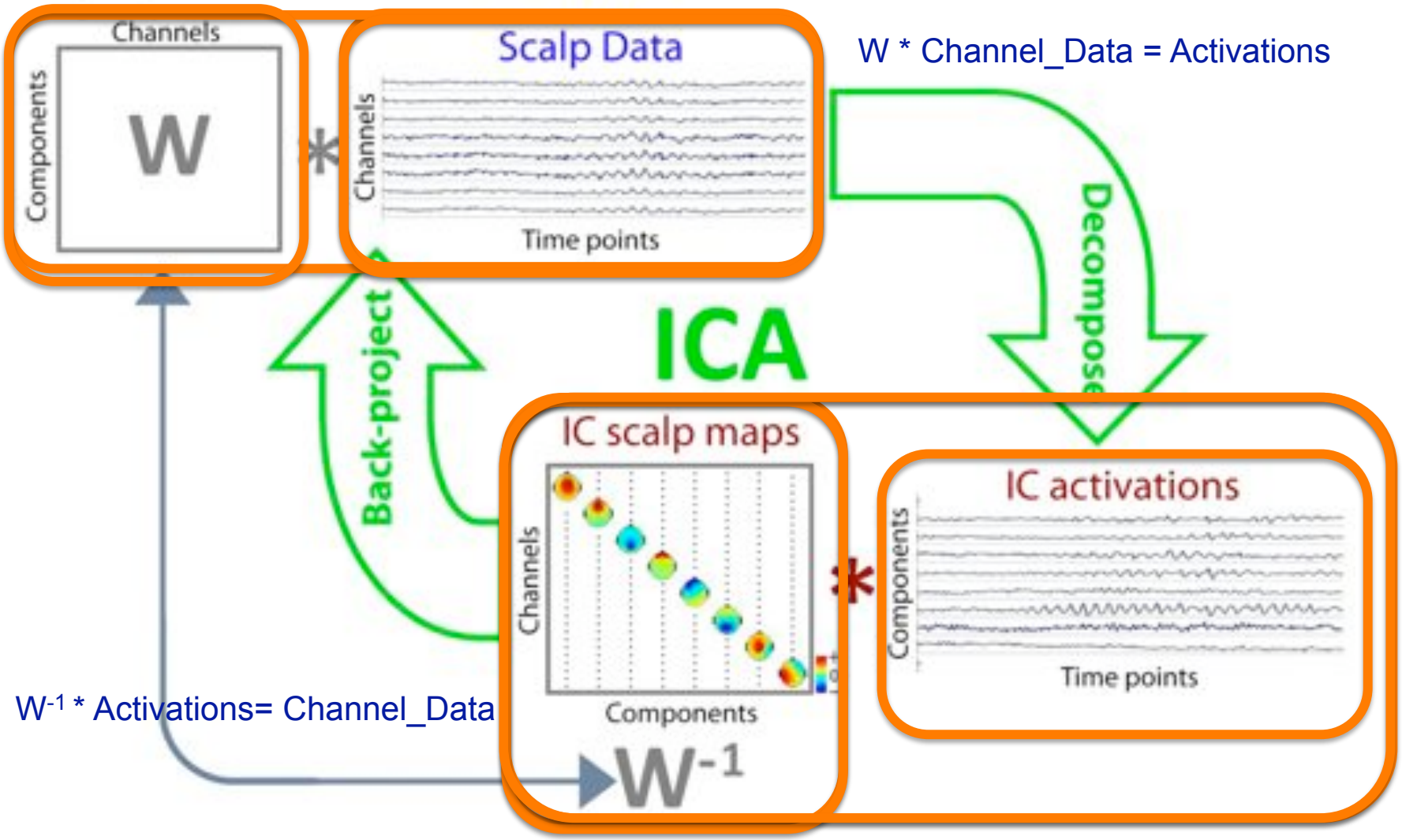
Equivalent dipoles

Single dipole source

Dual-symmetric dipole source

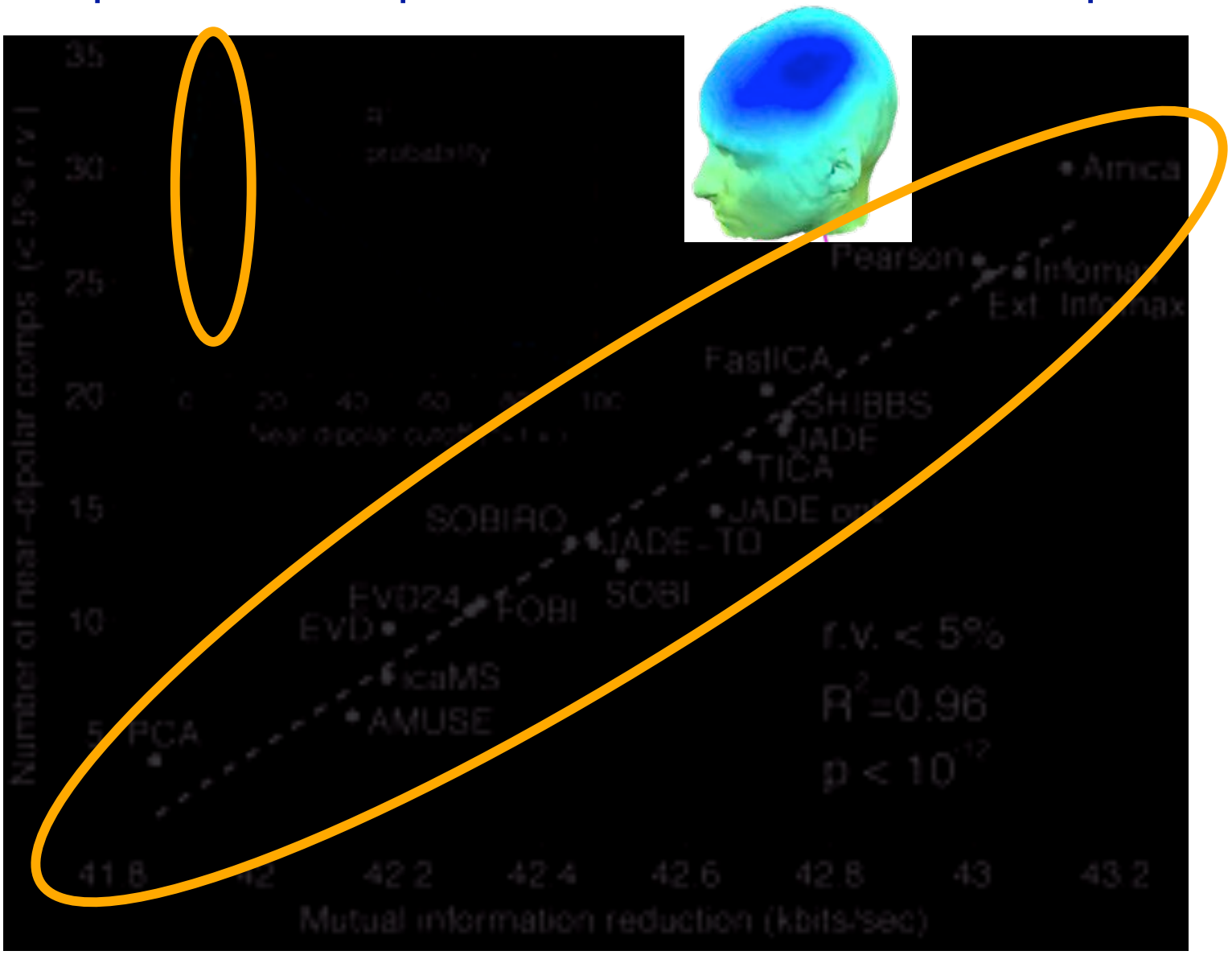
Julie Onton & S. Makeig (2006)

ICA is a linear data decomposition method



Makeig & Onton, 2011

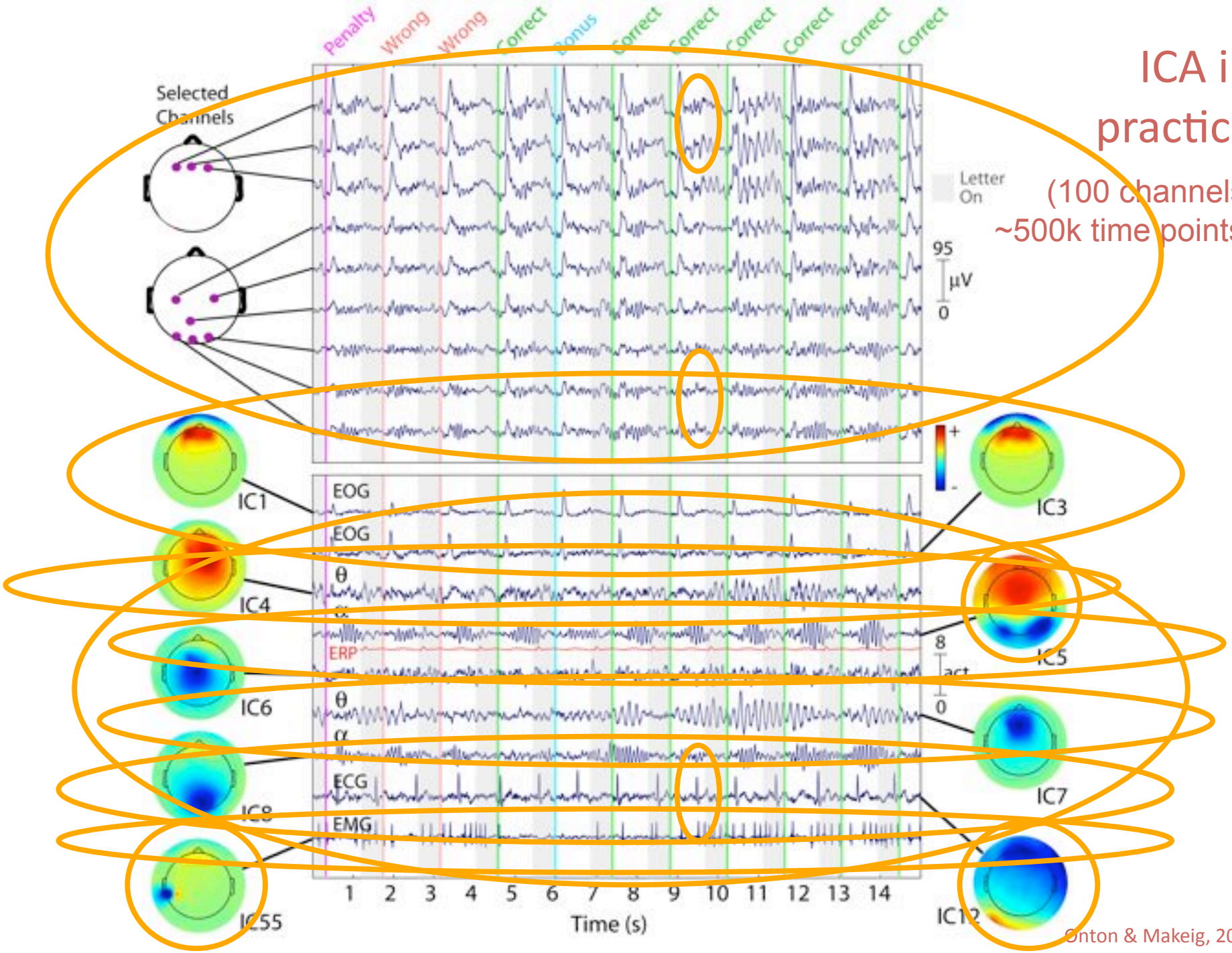
Independent Components of Human EEG are Dipolar



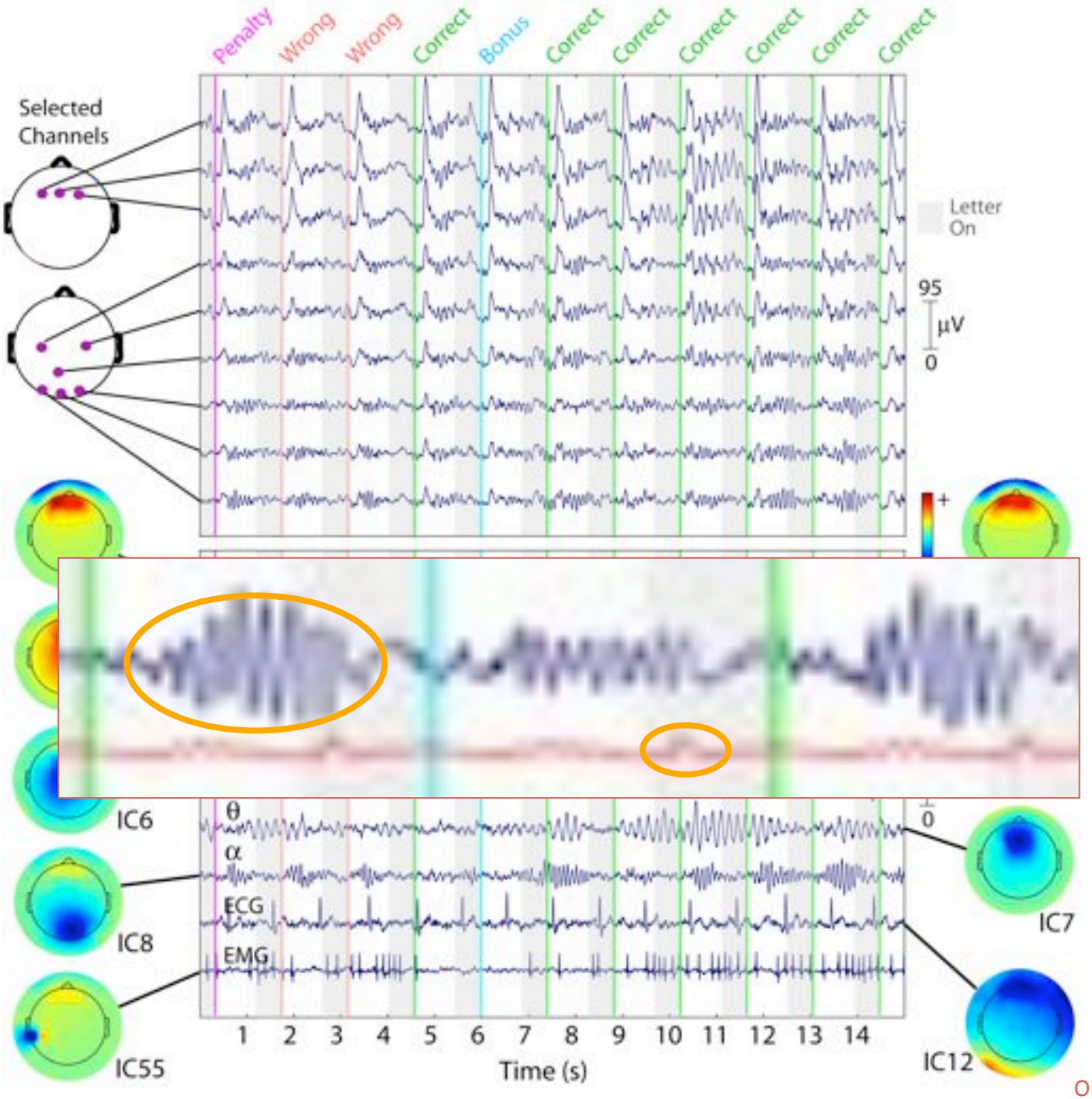
Delorme, Palmer, Makeig, 2011

ICA in practice

(100 channels, ~500k time points)



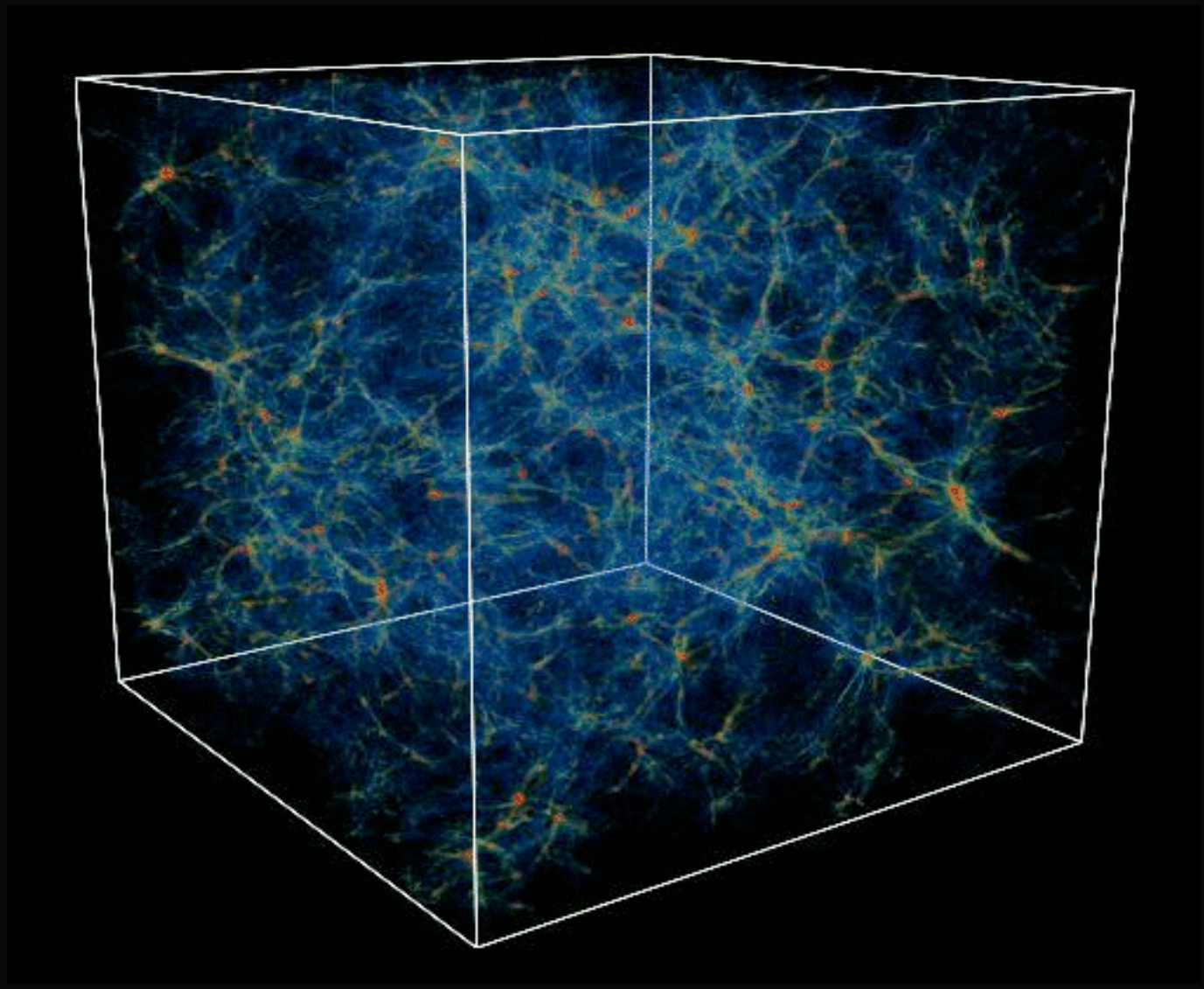
Onton & Makeig, 2006



Onton, Makeig (2006)

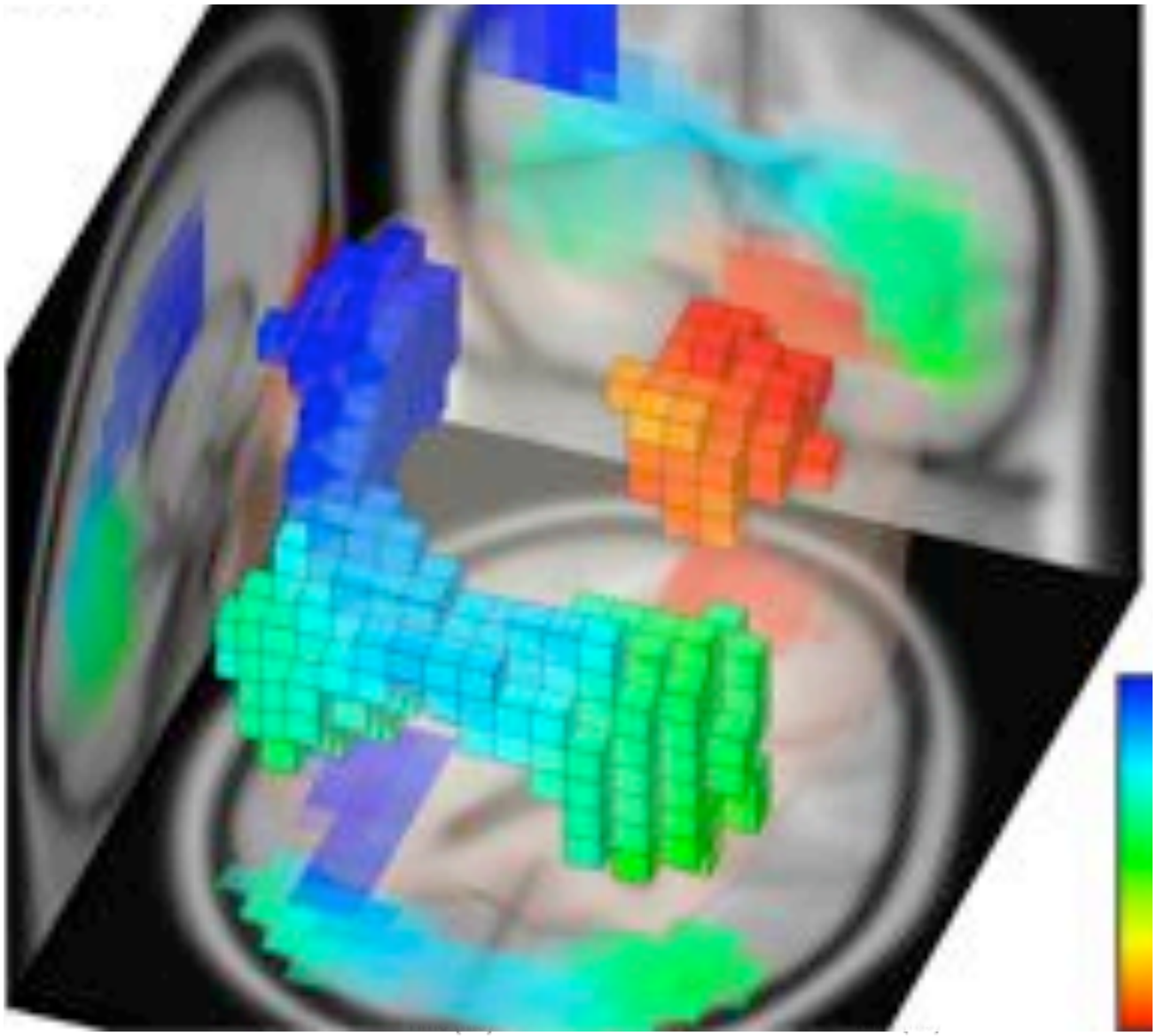
The 2-D Dome of the Sky

3-D structure of the Universe

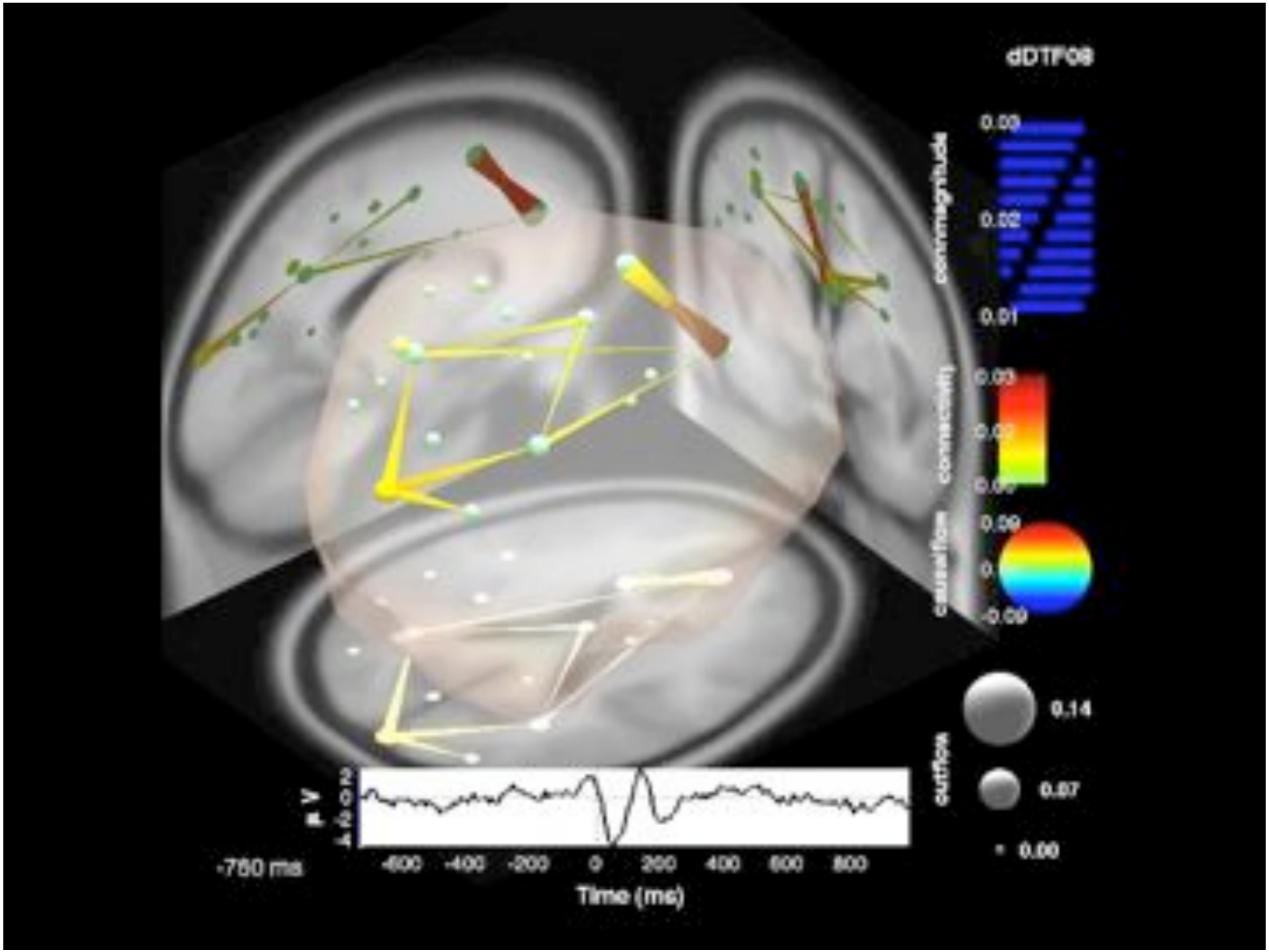


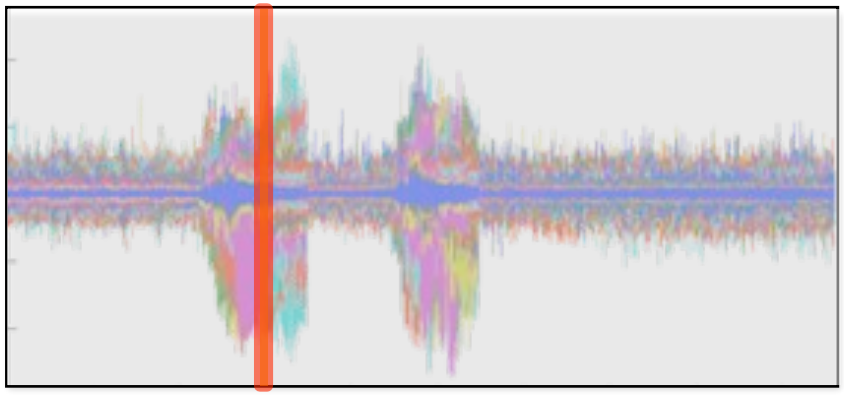
NASA 2009

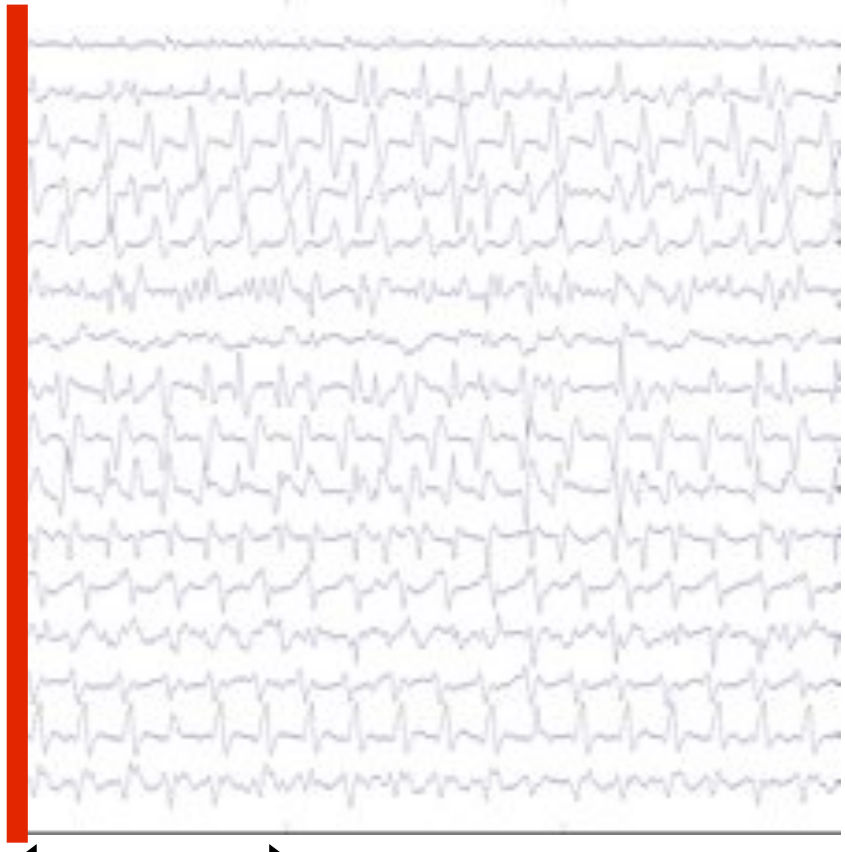
Measure Projection Toolbox



(RSVP) Nima Bigdely-Shamlo, 2011

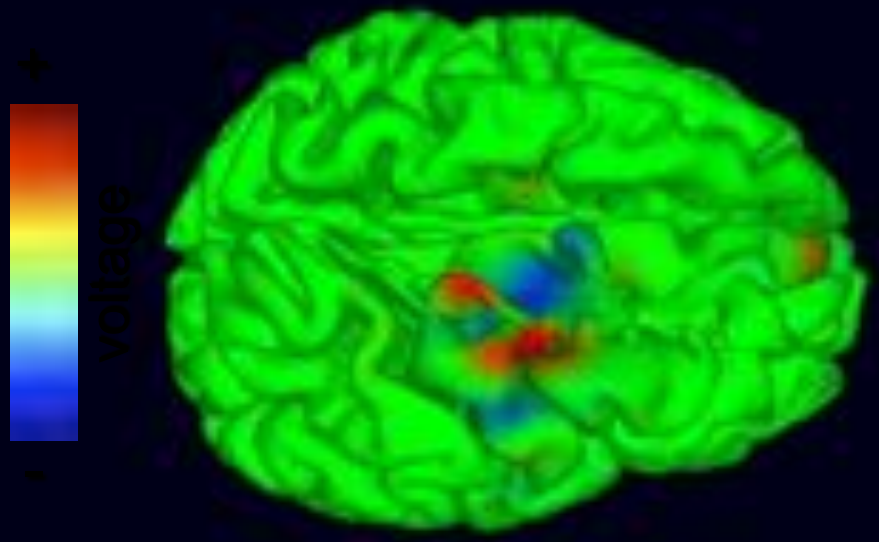

dDTF08
connectivity magnitude
0.03
0.02
0.01
causal flow
connectivity
0.03
0.00
-0.03
cortical flow
0.14
0.07
0.00
+750 ms
-600
-400
-200
0
200
400
600
800
Time (ms)





1 sec

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



Playback at 1/5 actual speed

T Mullen, 2011

Questions please!