Mining Cognitive Brain Dynamics I

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University of California San Diego

14th EEGLAB Workshop @ Beijing, China

June, 2012

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

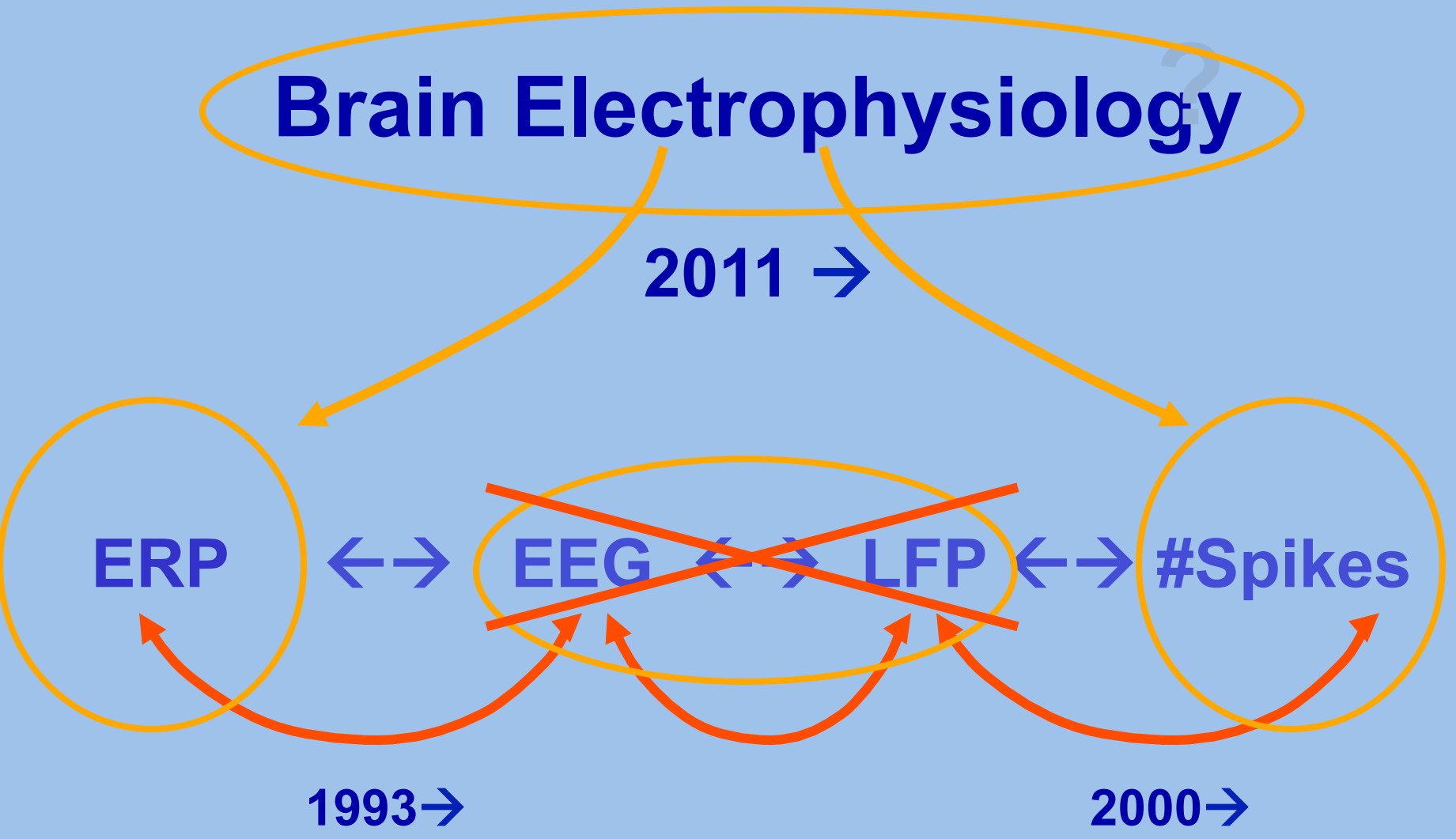
2009 ~1st commercial dry electrode EEG toys

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).

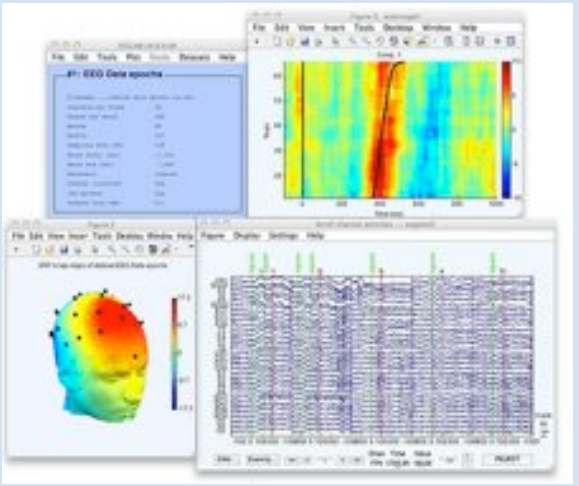
FIGURE 1–2.—Sample of the first EEG tracing taken at the Bradley Hospital, E. Providence, Rhode Island, by H. Jasper and L. Carmichael. Subject: Carl Pfaffmann. Date: July 9, 1934. Record, which shows prominent alpha rhythm of about 11.5 per second, was made with a Westinghouse, galvanometer-type, mirror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

S. Makeig 2010



S. Makeig, *TINS* 2002

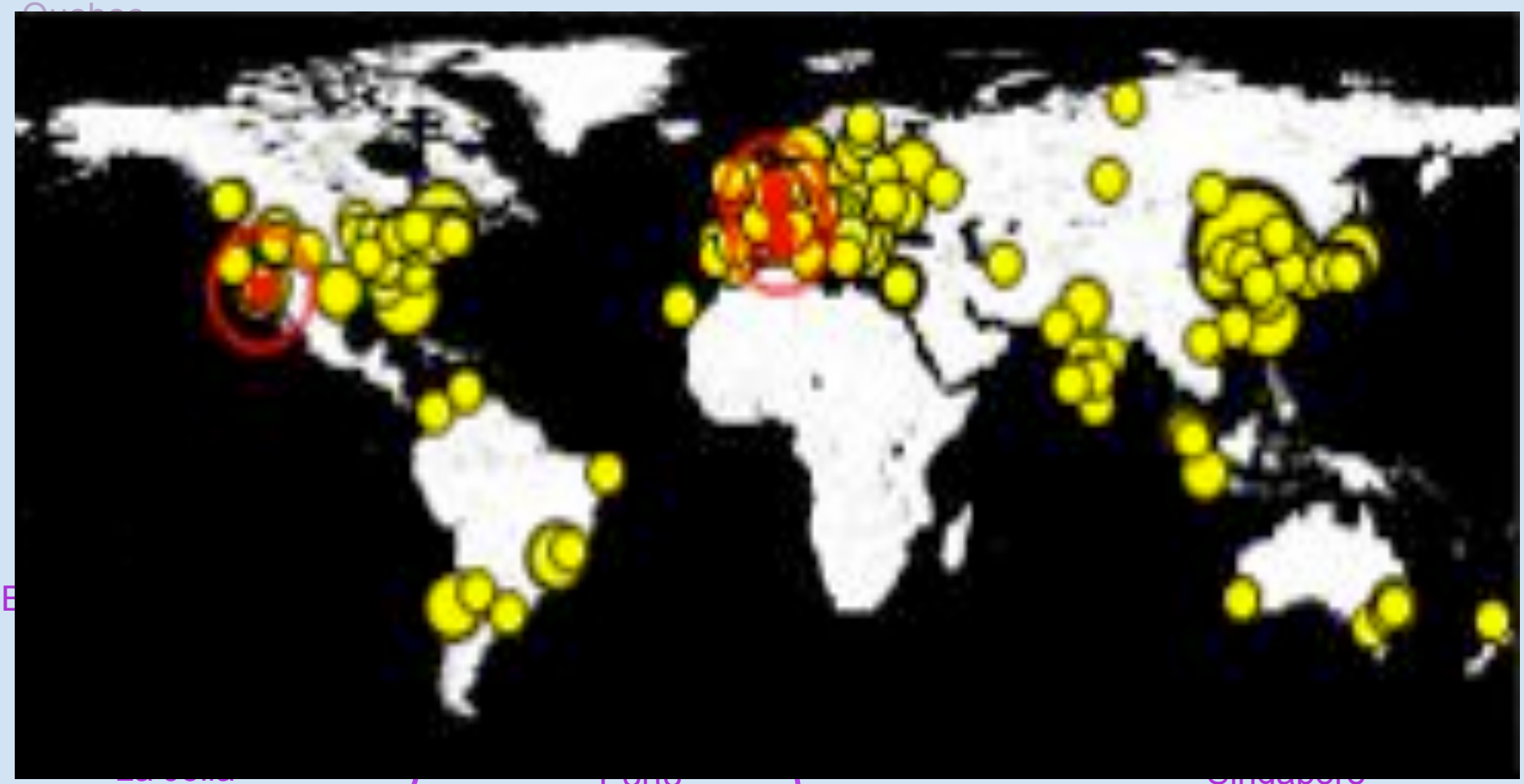
EEGLAB History



- 1993 – ERSP / ITC (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 – EEGLAB GUI design (Delorme)
- **2002 – 1st EEGLAB (sccn.ucsd.edu)**
- **2004 - 1st EEGLAB plug-ins**
- **2006 - 1st EEGLAB STUDY structure and component clustering tools**
- **2009 – NFT (Neuroelectromagnetic Forward Head Modeling Toolbox)**
- **2009 – New toolboxes: SIFT, BCILAB, MPT**
- **2012 - HeadIT resource, ERICA (Experimental Real-time Interactive Control & Analysis)**
- **2012 – Workshop in Beijing**

S. Makeig 2010

EEGLAB Workshops



S. Makeig 2011

Arnaud Delorme

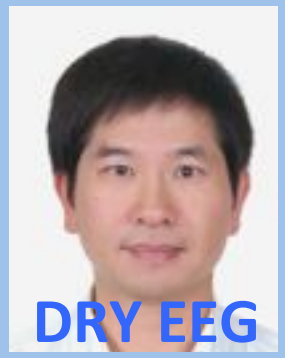
Christian Kothe

David Groppe

Julie Onton

Jason Palmer

Tim Mullen



Tzyy-Ping Jung

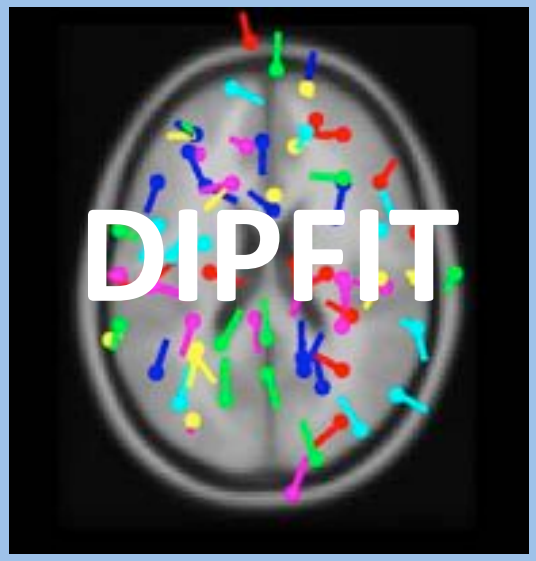
Alejandro Ojeda

Tony Bell

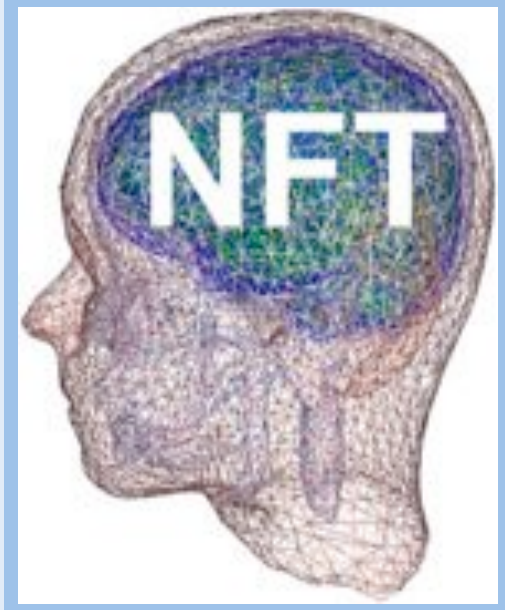
Zeynep
Akalin Acar

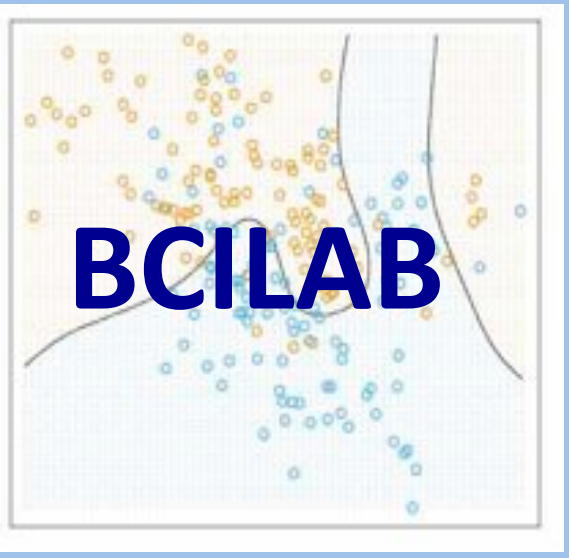
Nima Bigdely
Shamlo

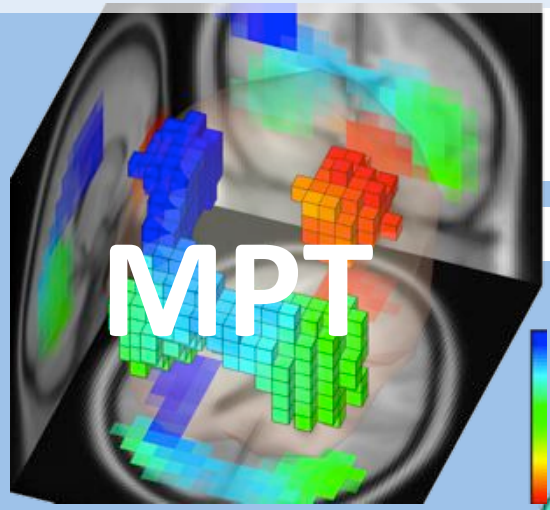
S. Makeig (2011)

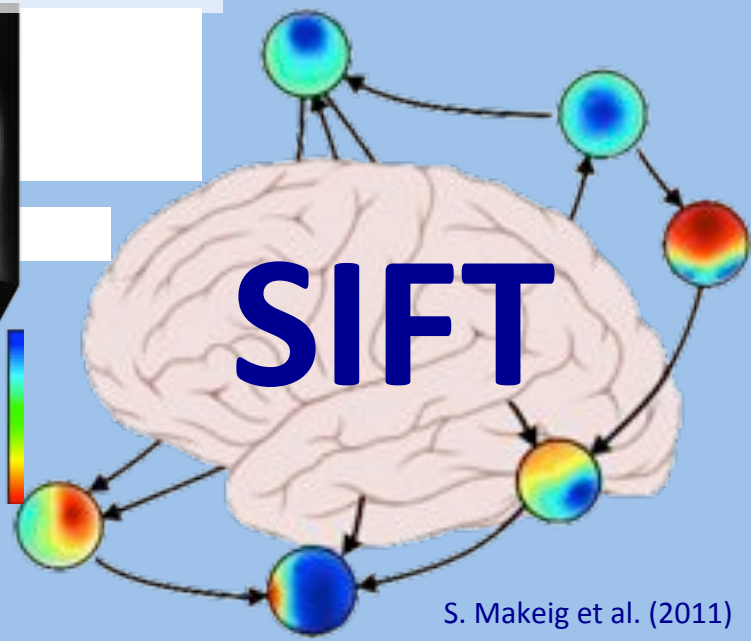


EEGLAB Plug-In Toolboxes

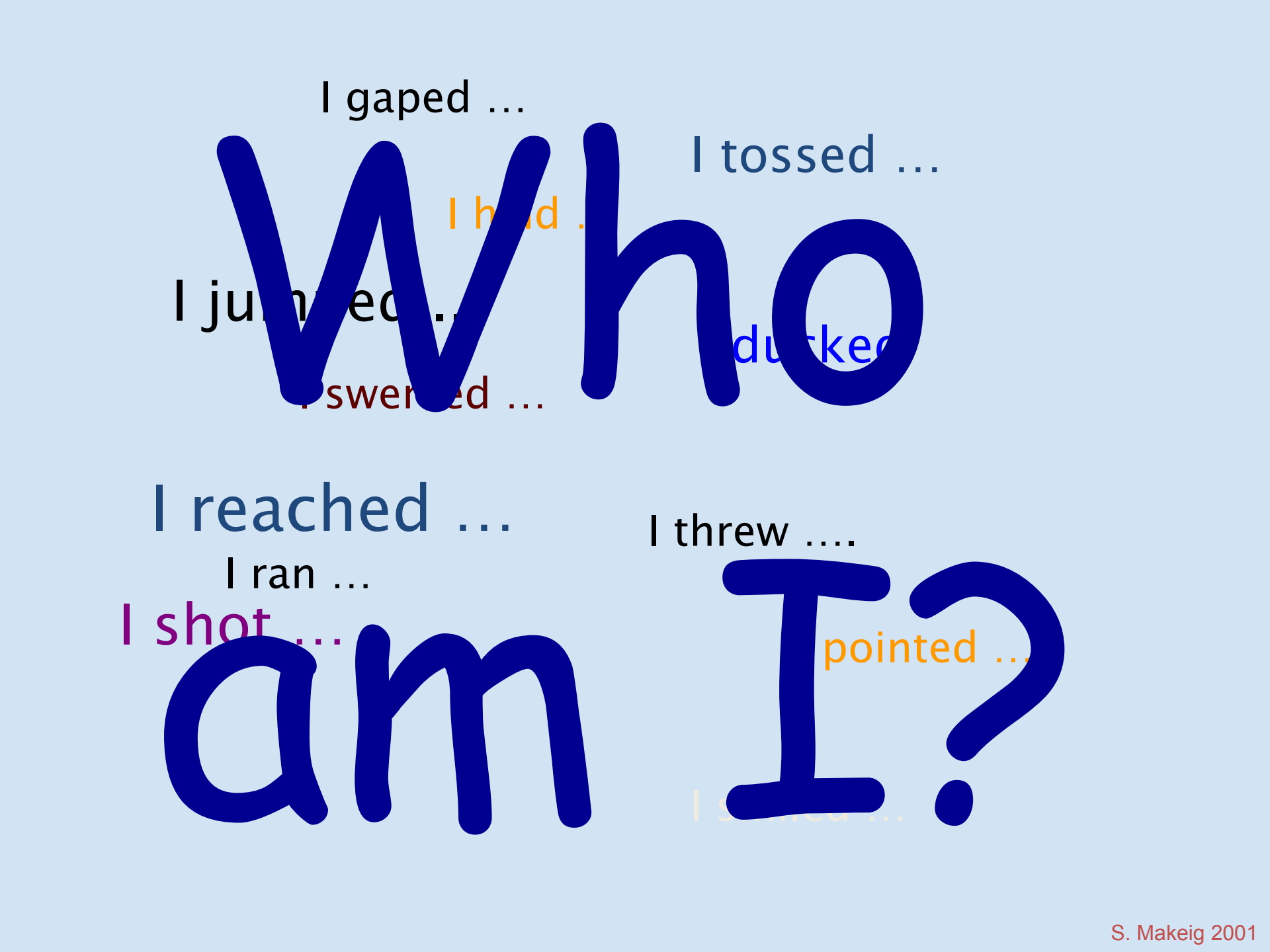




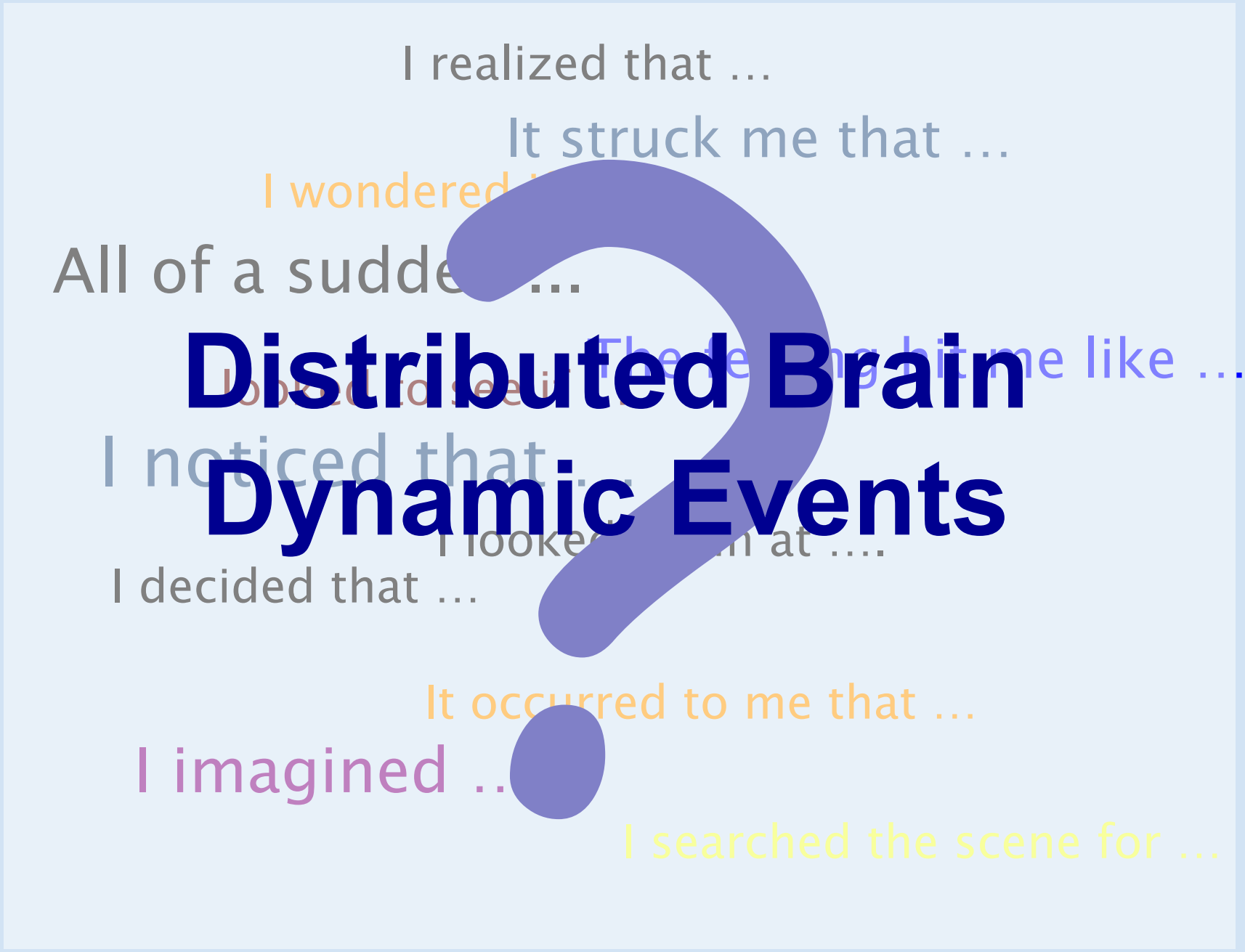




S. Makeig et al. (2011)



S. Makeig 2001



Distributed Brain Dynamic Events

I realized that …

It struck me that …

I wondered i

All of a sudde …

The te ng hit me like …

I looked to see i

I noticed that …

I looke n at ….

I decided that …

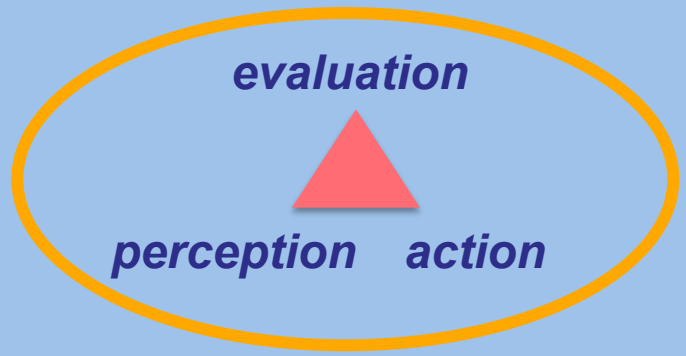
It occurred to me that …

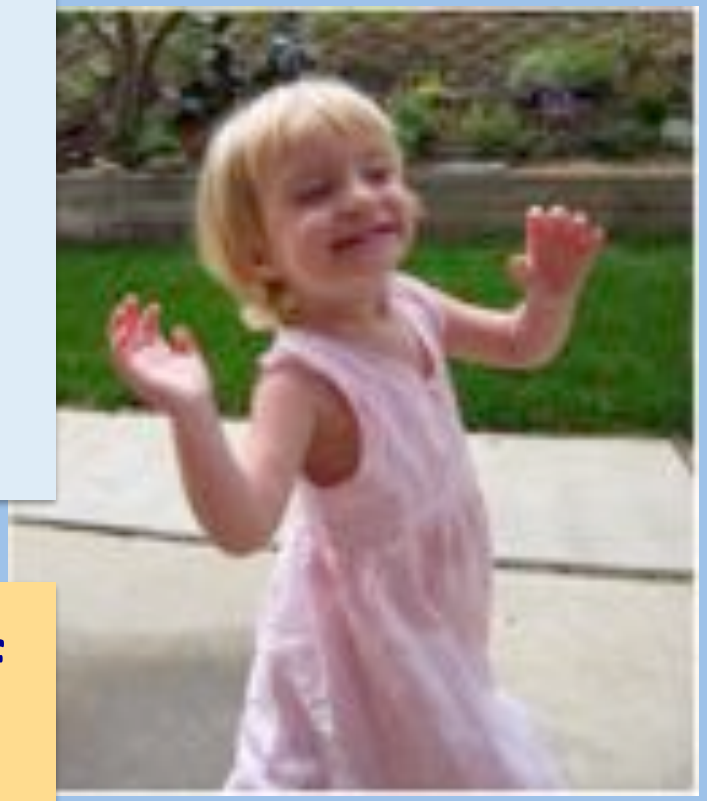
I imagined …

I searched the scene for …

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.

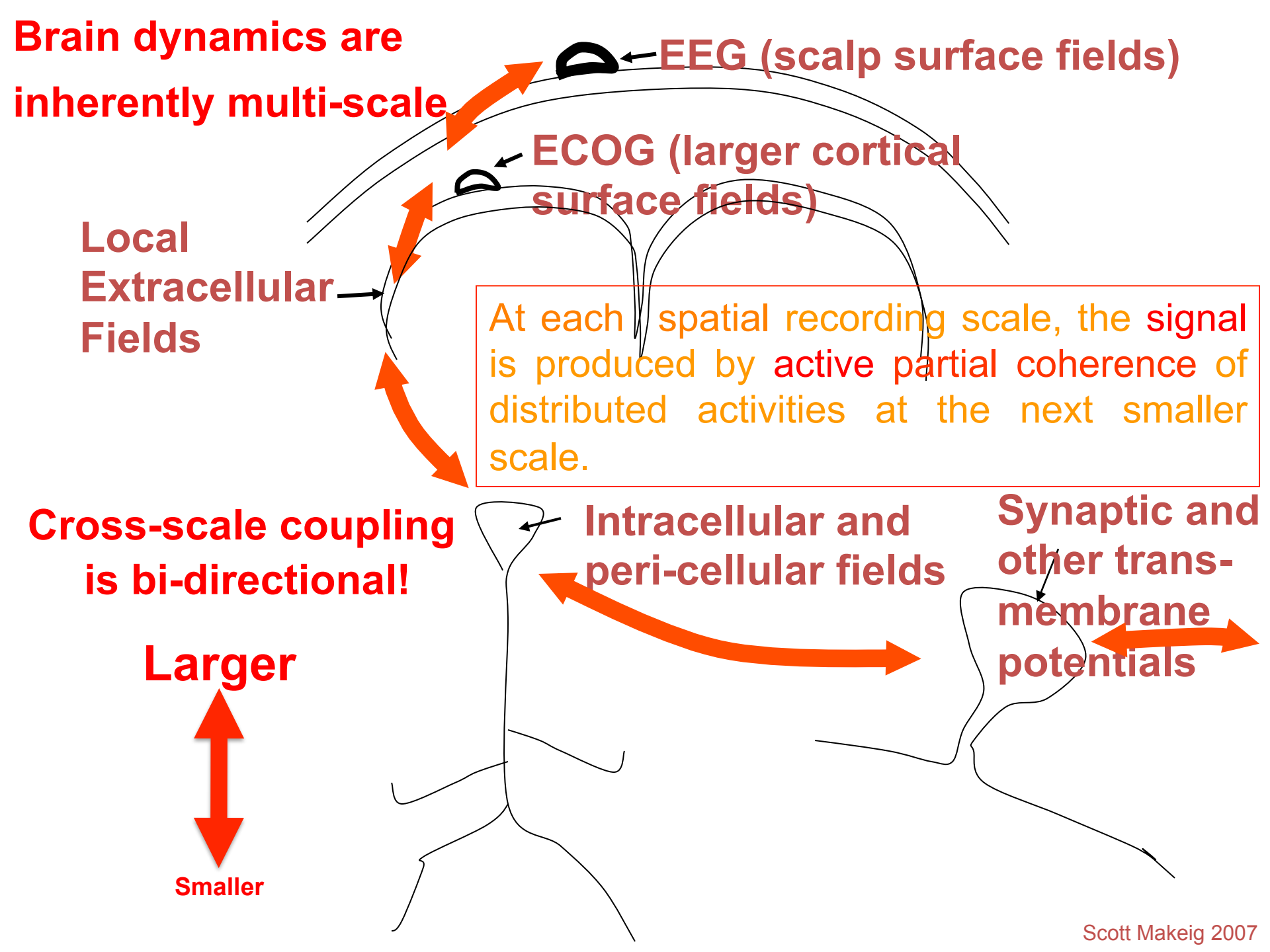


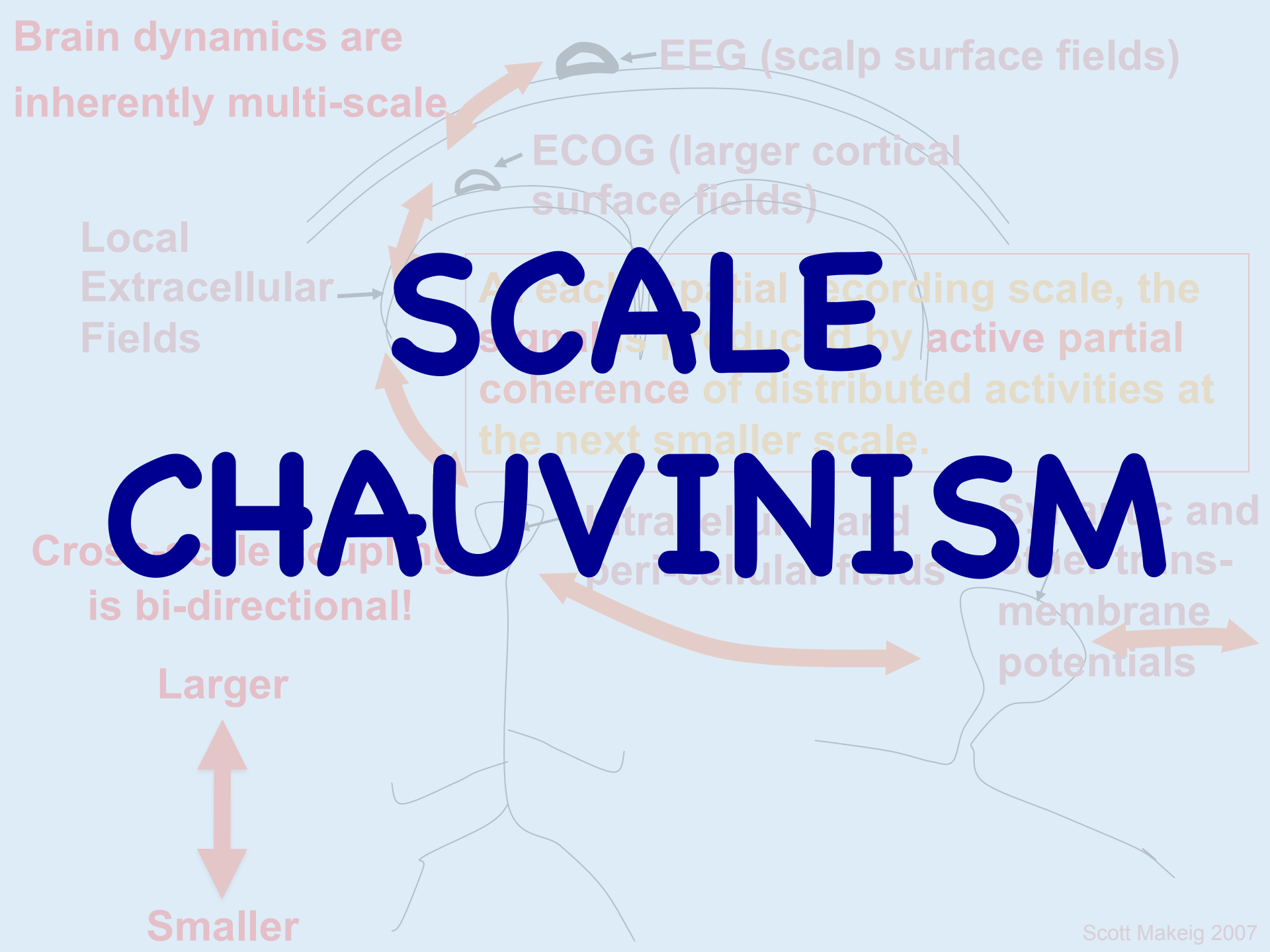


Brains meet the challenge of the moment!

S. Makeig 2011

What is EEG?

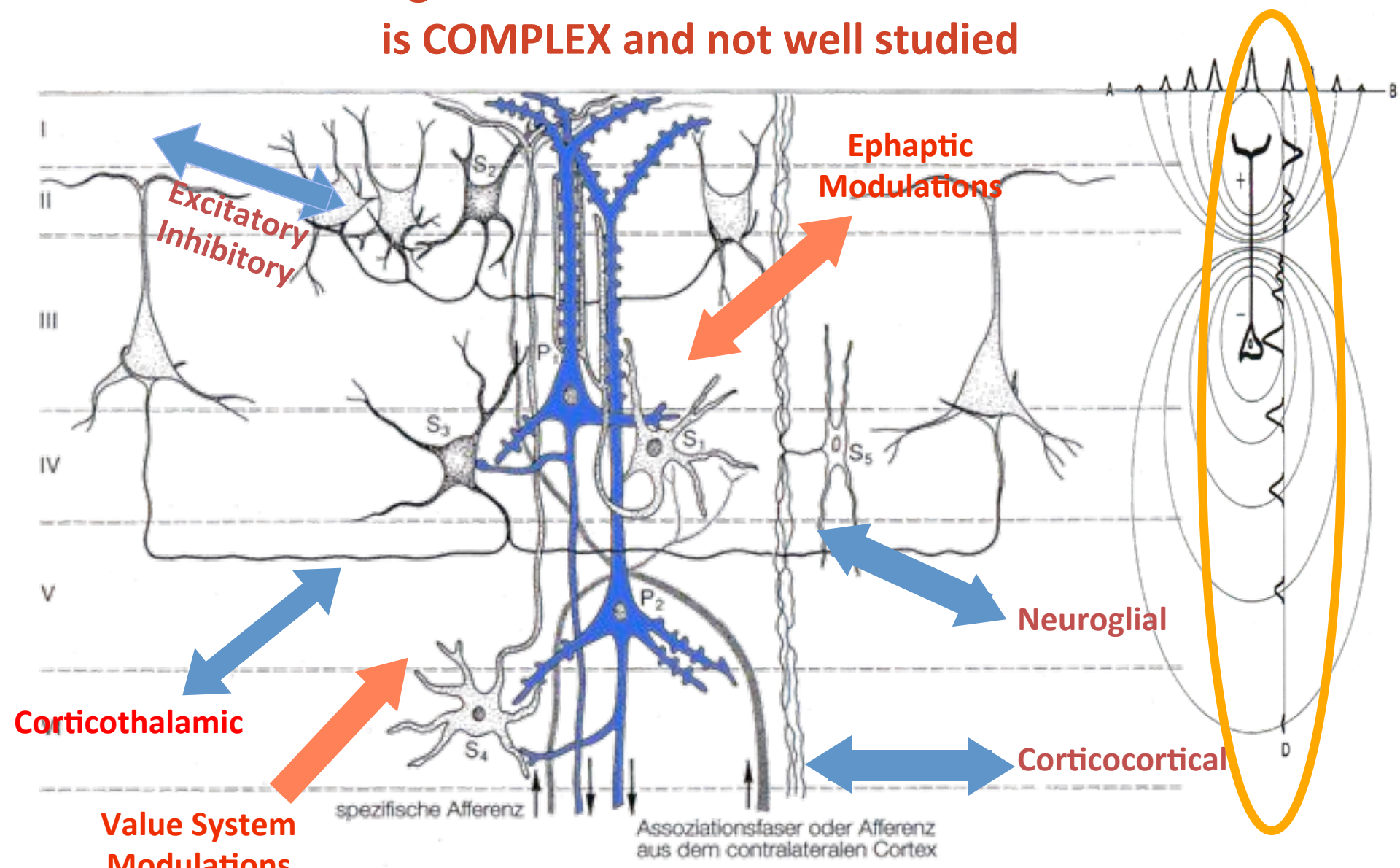

Brain dynamics are inherently multi-scale
EEG (scalp surface fields)
ECOG (larger cortical surface fields)
Local Extracellular Fields
At each spatial recording scale, the signal is produced by active partial coherence of distributed activities at the next smaller scale.
Cross-scale coupling is bi-directional!
Larger
Smaller
Intracellular and peri-cellular fields
Synaptic and other trans-membrane potentials
Scott Makeig 2007



SCALE CHAUVINISM

Scott Makeig 2007

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



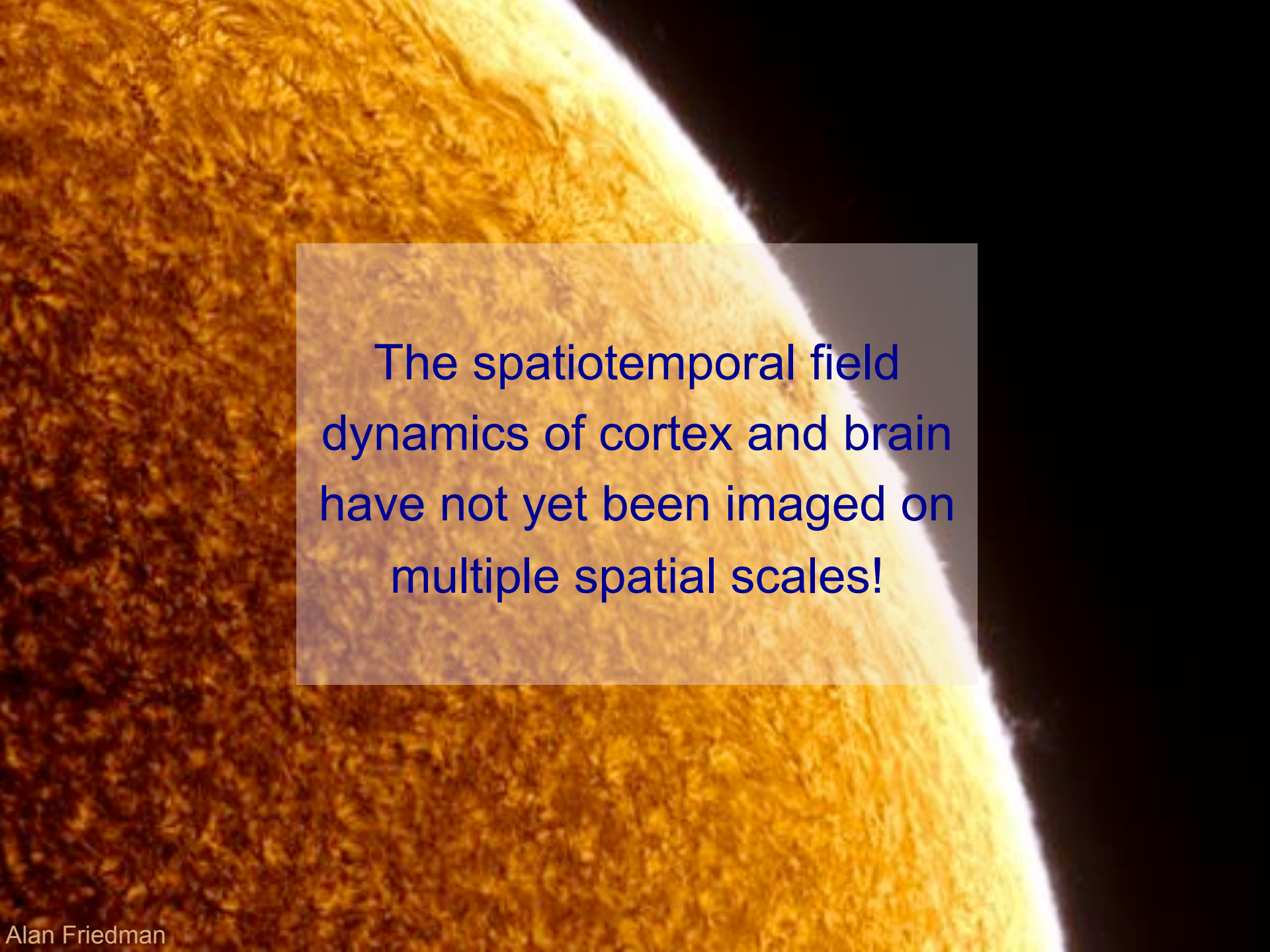
S. Makeig 2007

Phase cones (Freeman)

Avalanches (Plenz)

Scott Makeig 2008

Alan Friedman


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

Functional Brain Imaging

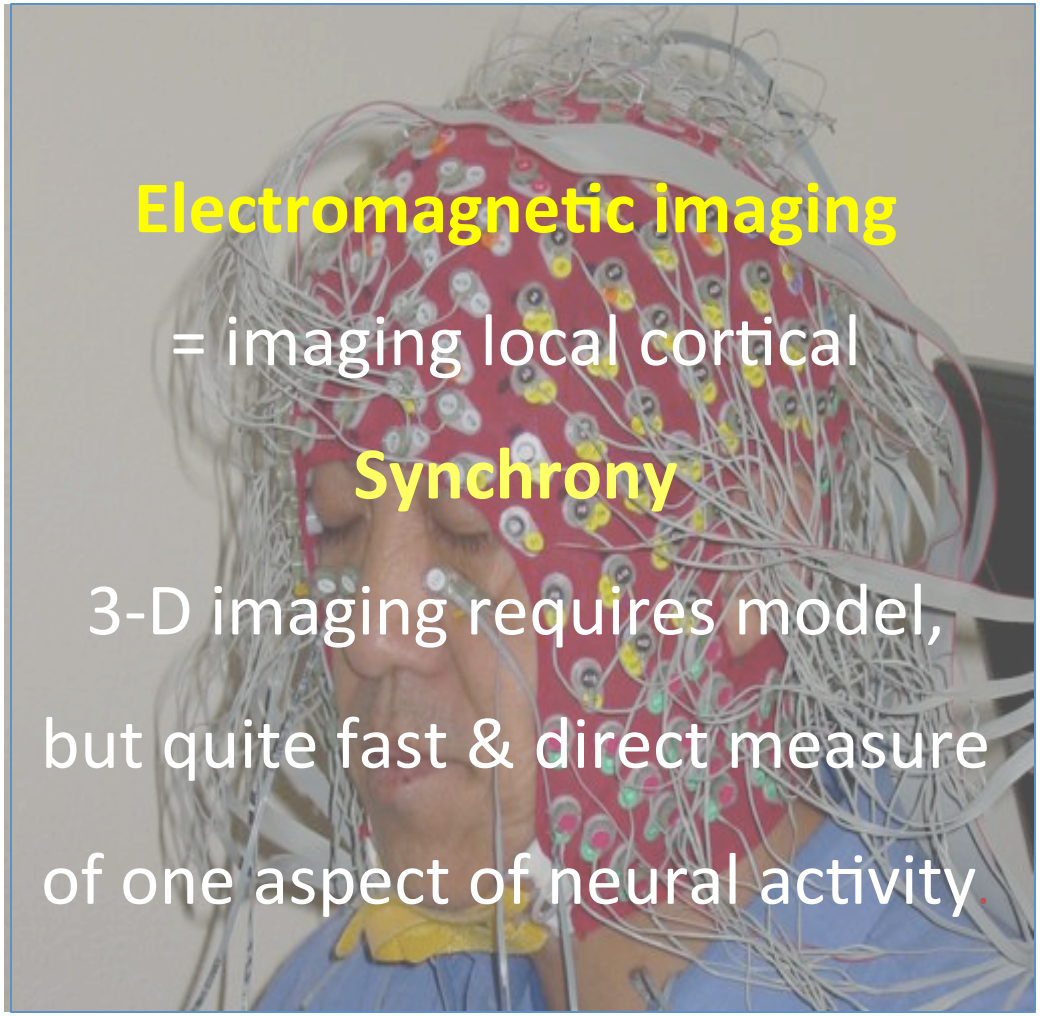
Hemodynamic imaging

= imaging local brain

Energy

Direct 3-D inverse model,

but quite slow & indirect



S. Makeig 2010

How to measure EEG?

Makeig (2006)

MICRO

BRAIN ? BEHAVIOR

SPIKES

LFP

ECOG

EEG

MACRO

ERP

Recorded !?

RT

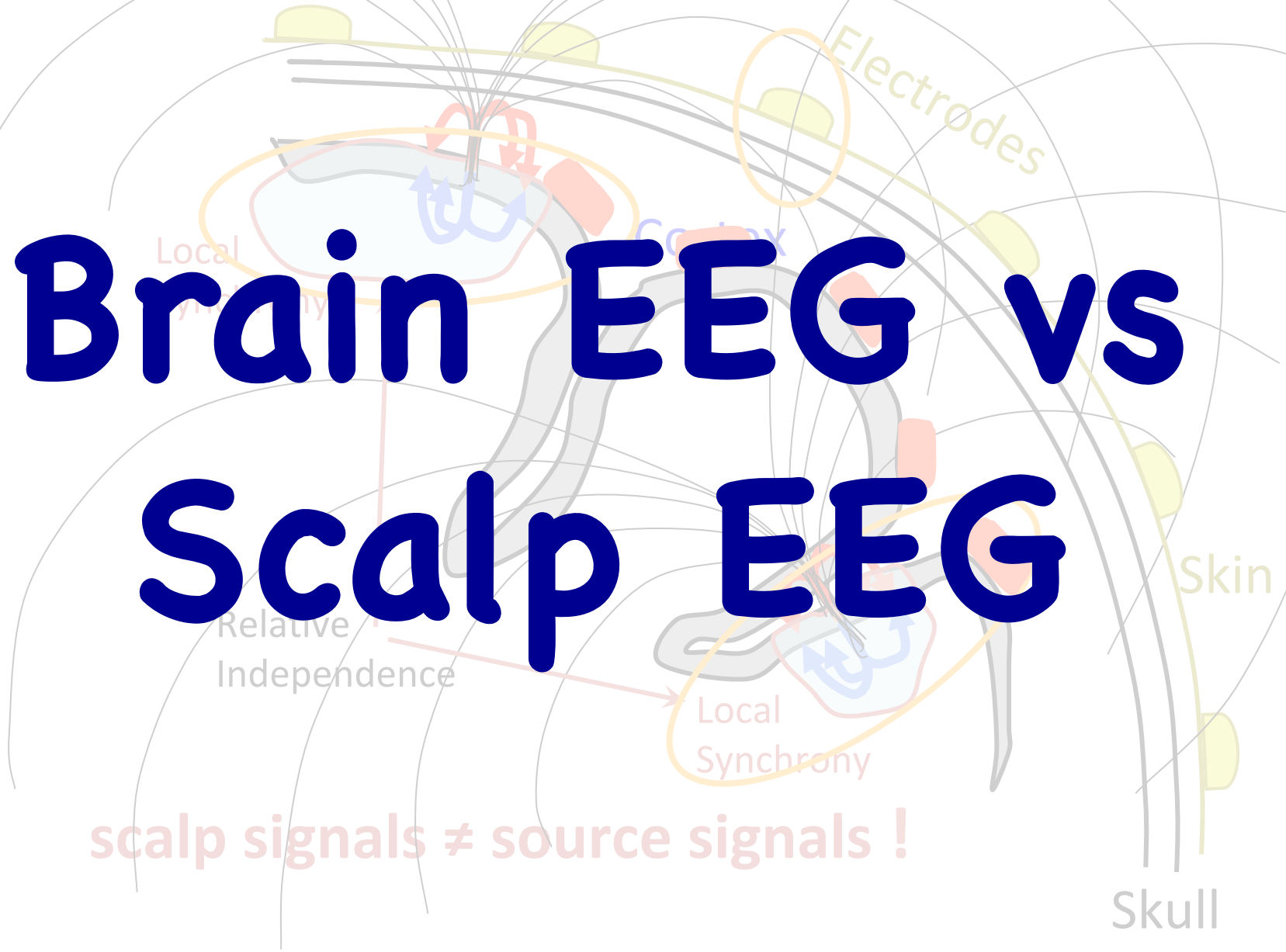
~1 Hz

~1 MHz

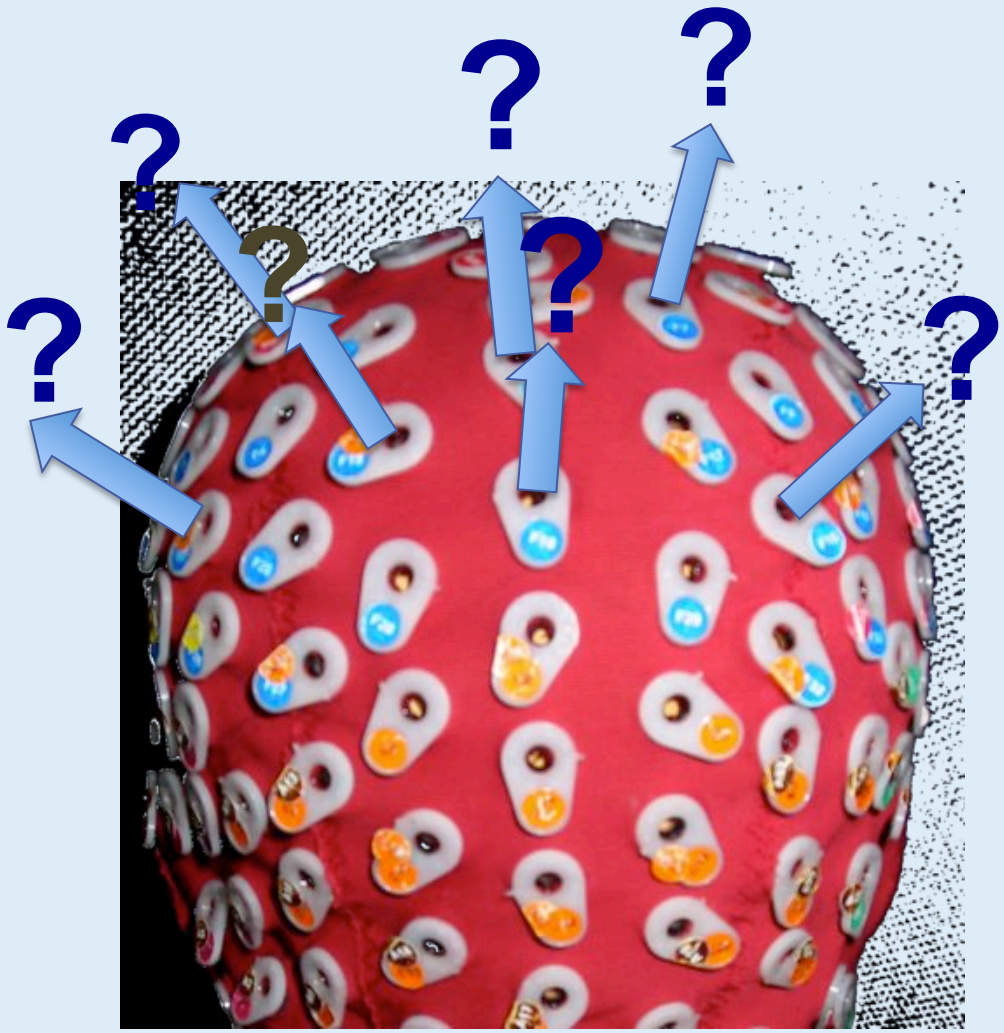
~1,000,000 GHz

S. Makeig 2007

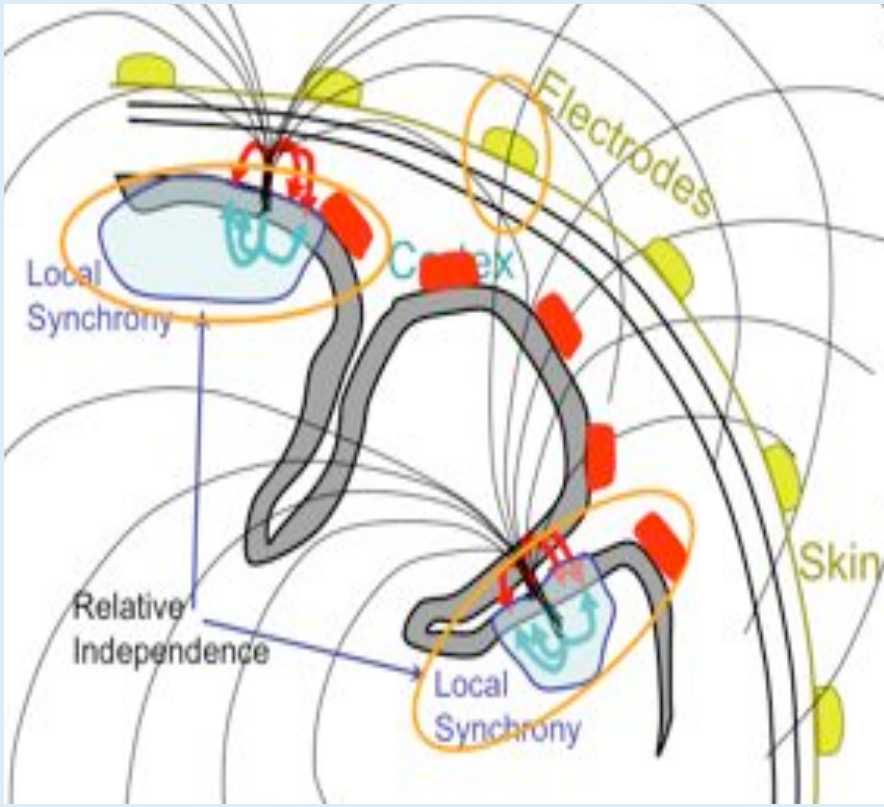
Brain EEG vs Scalp EEG



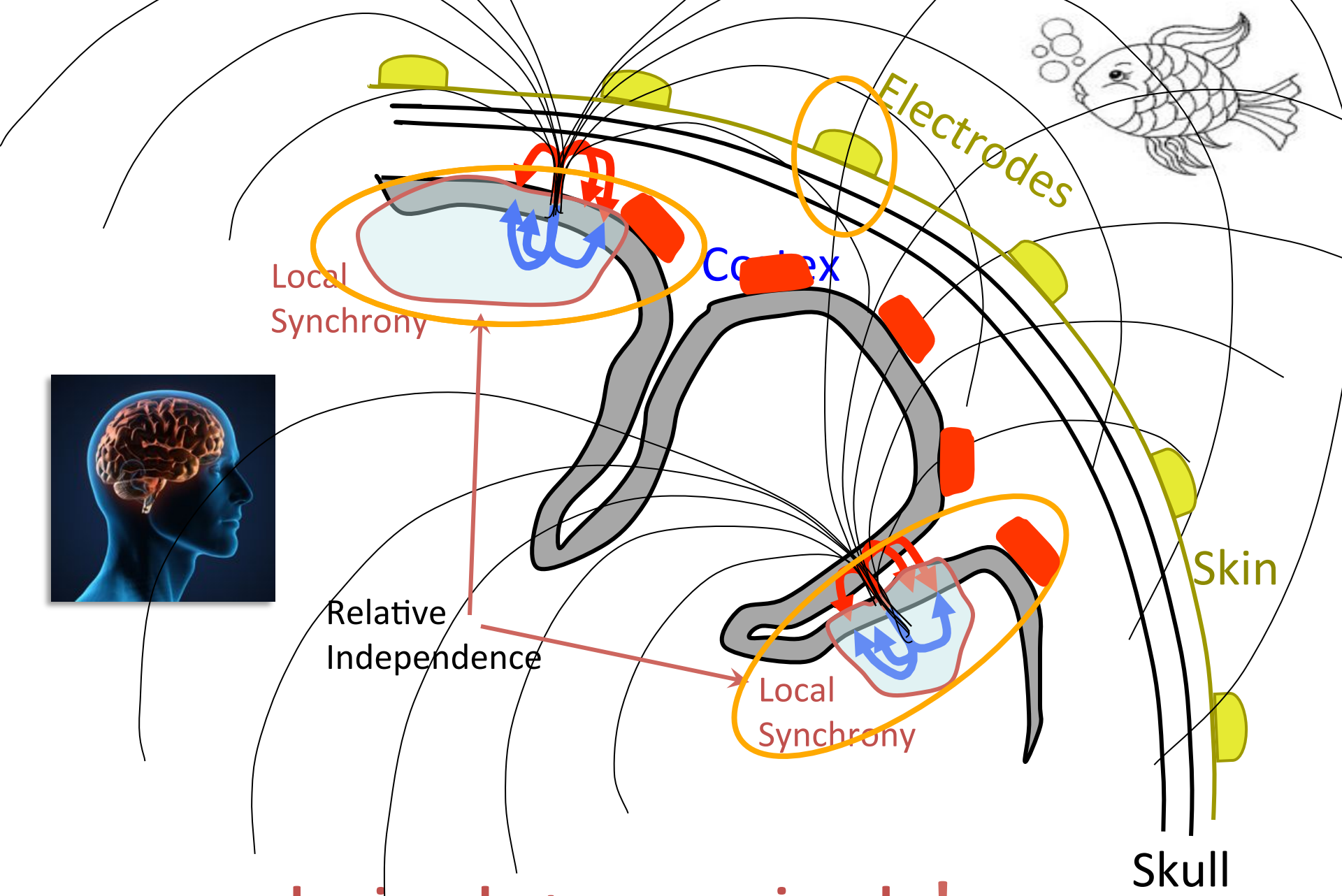
Naïve 2-D interpretation of EEG signals?



Cortical EEG signal projection patterns as point processes



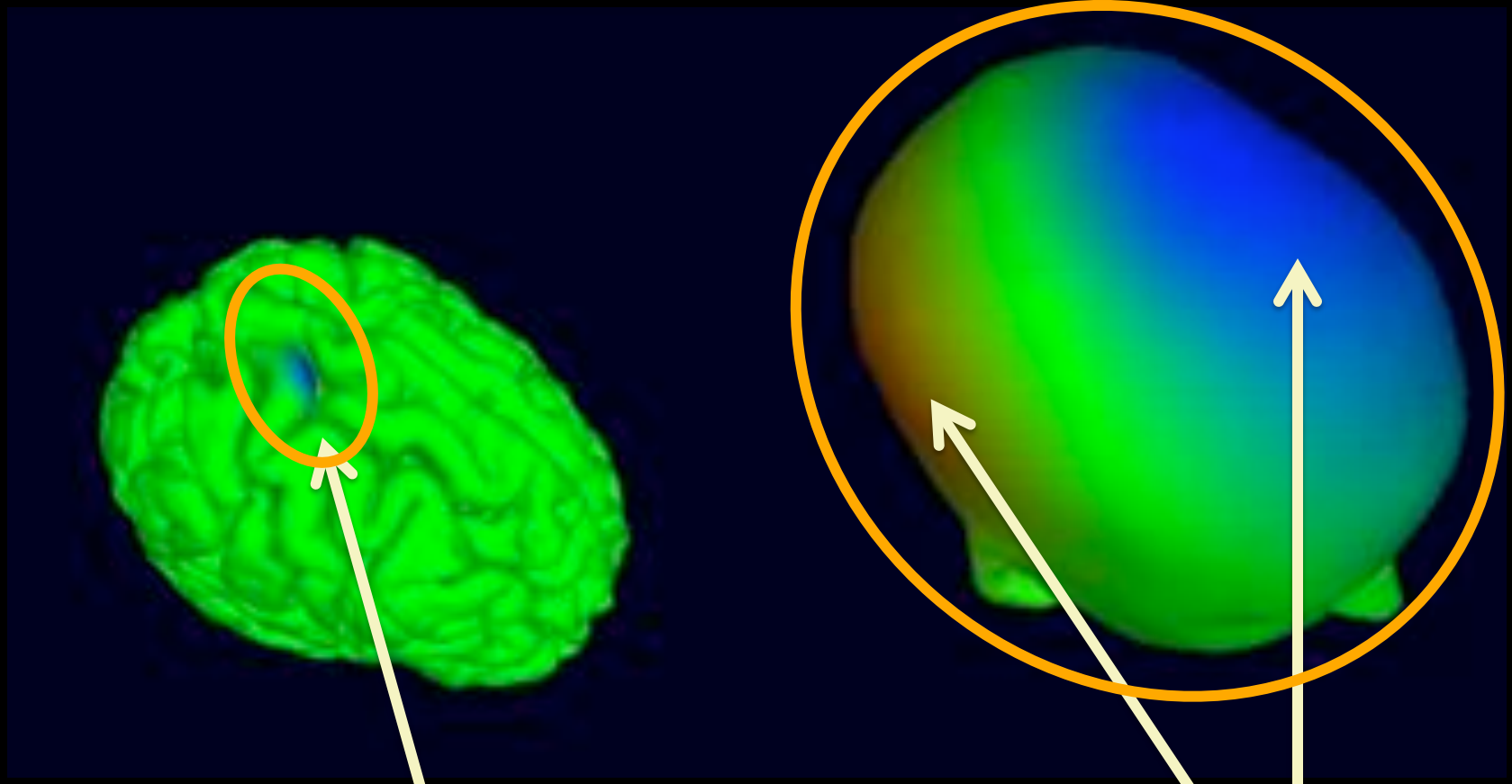
Actual cortical source volume conduction patterns (cartoon)



scalp signals ≠ source signals !

S. Makeig 2007

The very broad EEG point-spread function



Simulated parietal source

Very broad projected scalp potentials

Akalin Acar & Makeig 2010

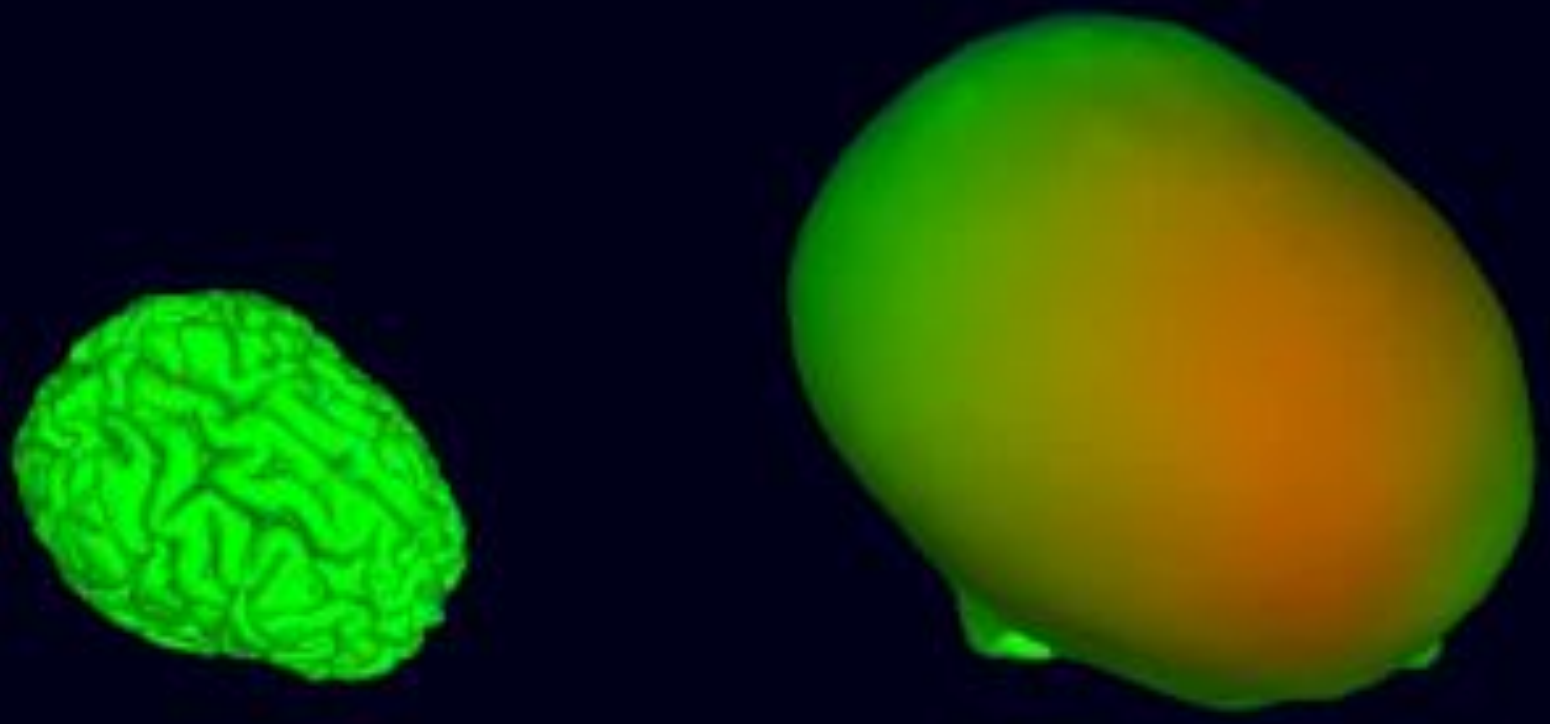
The very broad EEG point-spread function

[Nsources_alpha.mp4]

Simulated EEG summing cortical sources
(animation at 1/5th real time)

Akalin Acar & Makeig 2010

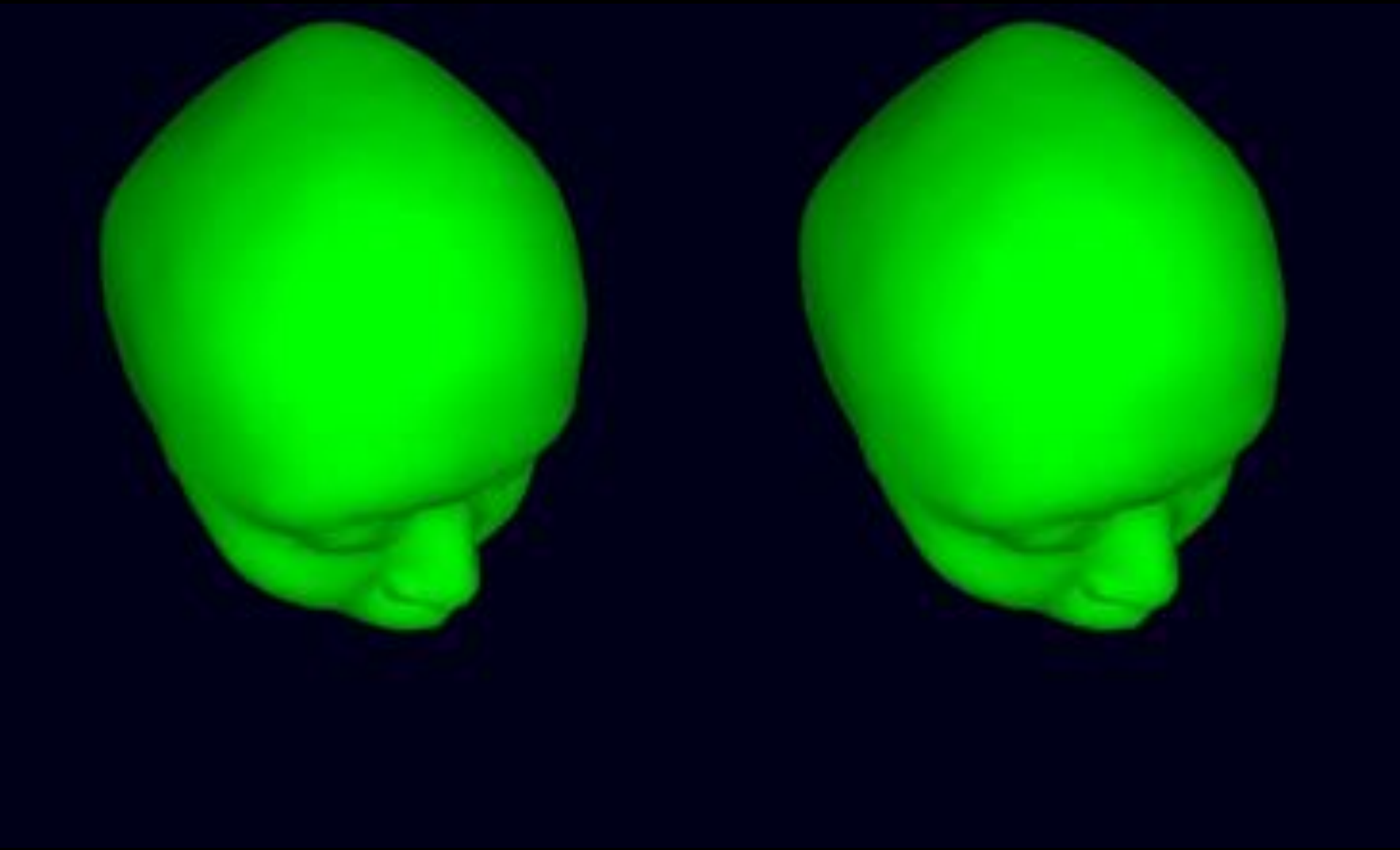
The very broad EEG point-spread function



Simulated EEG summing 30 cortical sources
(animation at 1/5th real time)

Akalin Acar & Makeig 2010

Effects of non-brain artifacts on scalp EEG



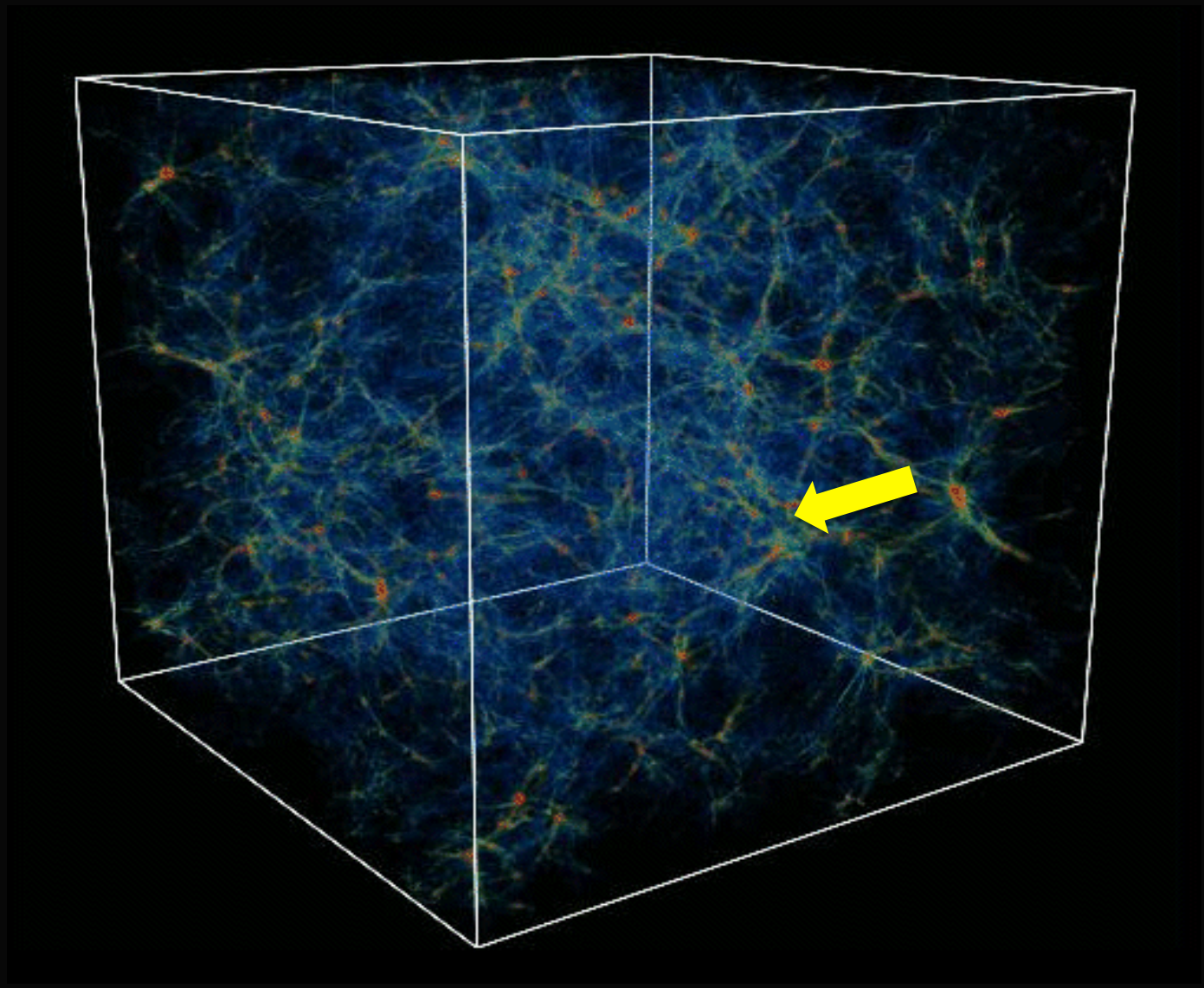
Without non-brain sources

Including non-brain sources

The 2-D Dome of the Sky

Scott Makeig 2008

3-D structure of the Universe



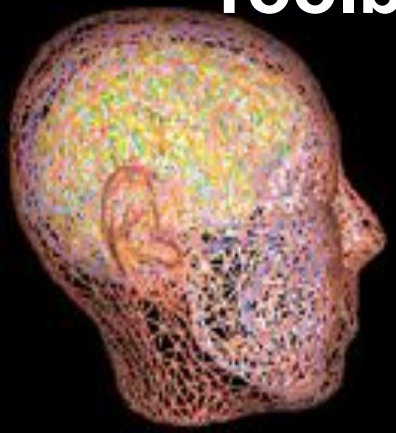
NASA 2009

Neuroelectromagnetic Forward Head Modeling Toolbox (NFT)

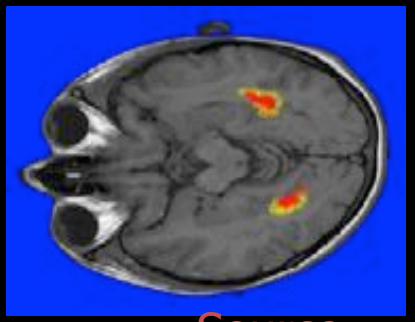
Electromagnetic source localization using realistic head models

BUT how to find a 'simple' map representing the projection of a single cortical source?

Solve the forward problem using realistic head models (BEM)



Simple Map



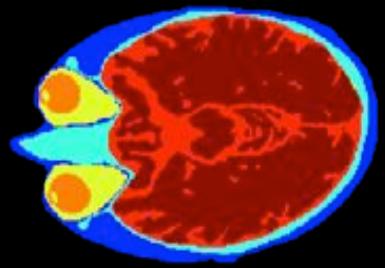
Source Image

Sensor Co-Registration

Signal Processing

Mesh generation

MRI



Segmentation

EEG/MEG

Zeynep Akalin Acar, & Scott Makeig '11

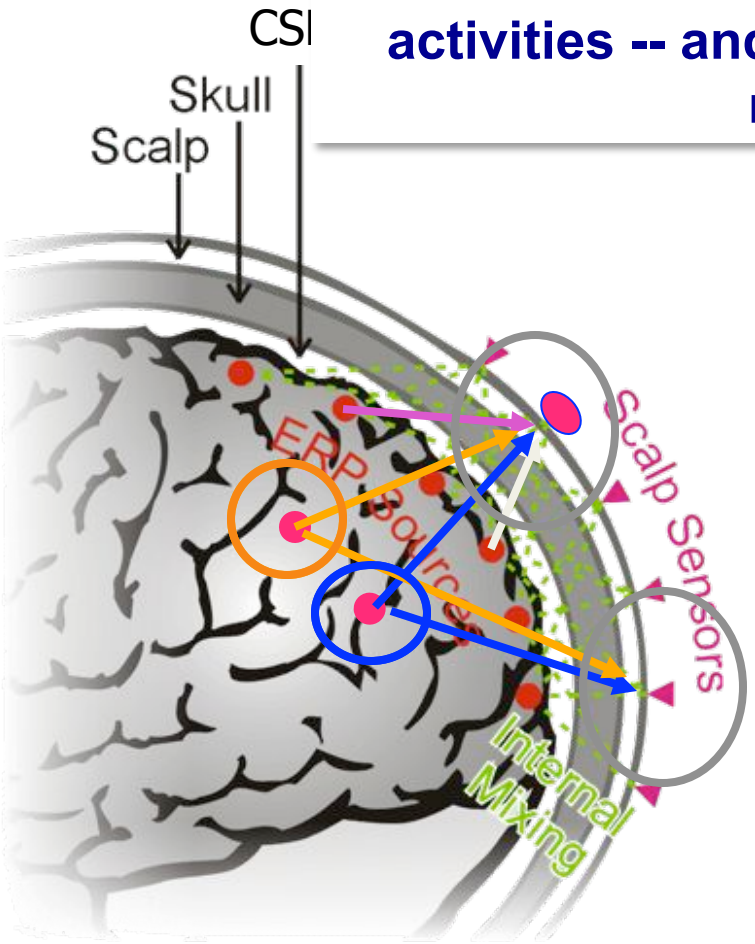
Information based signal processing

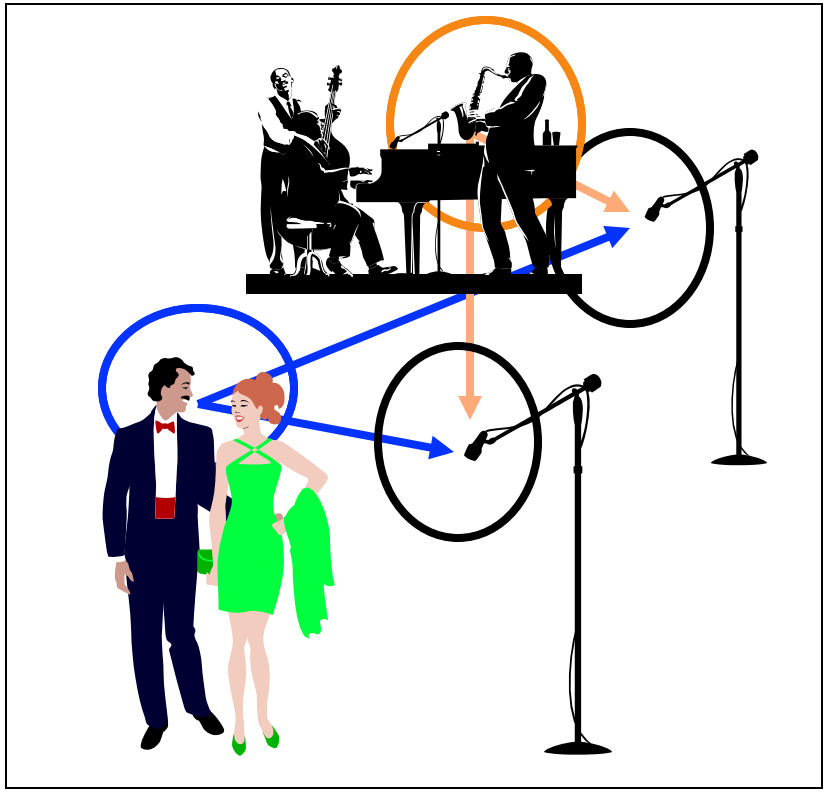
Makeig (2006)

Blind EEG Source Separation by Independent Component Analysis

Tony Bell, developer of Infomax ICA

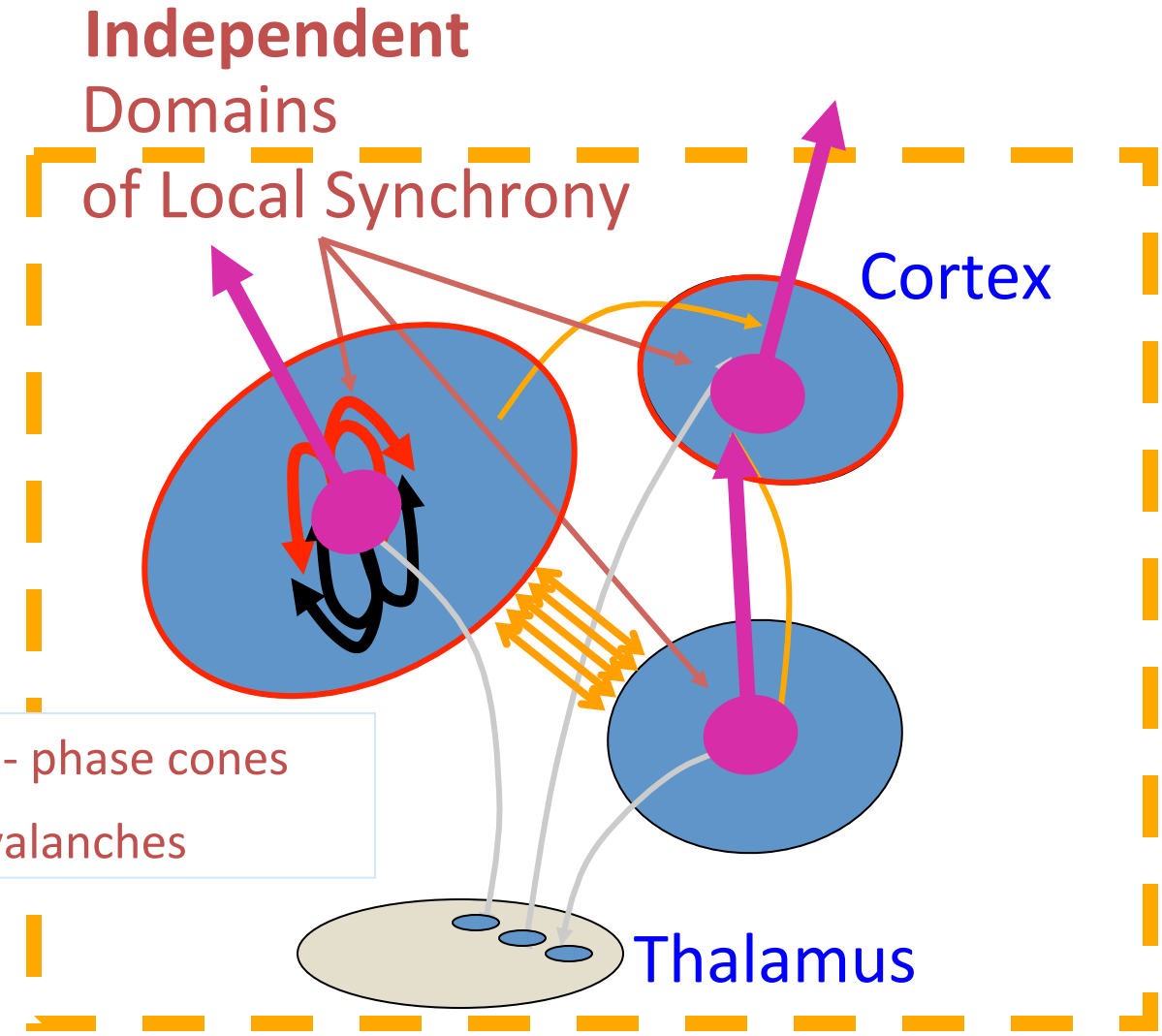
ICA can find distinct EEG source activities -- and their 'simple' scalp maps!





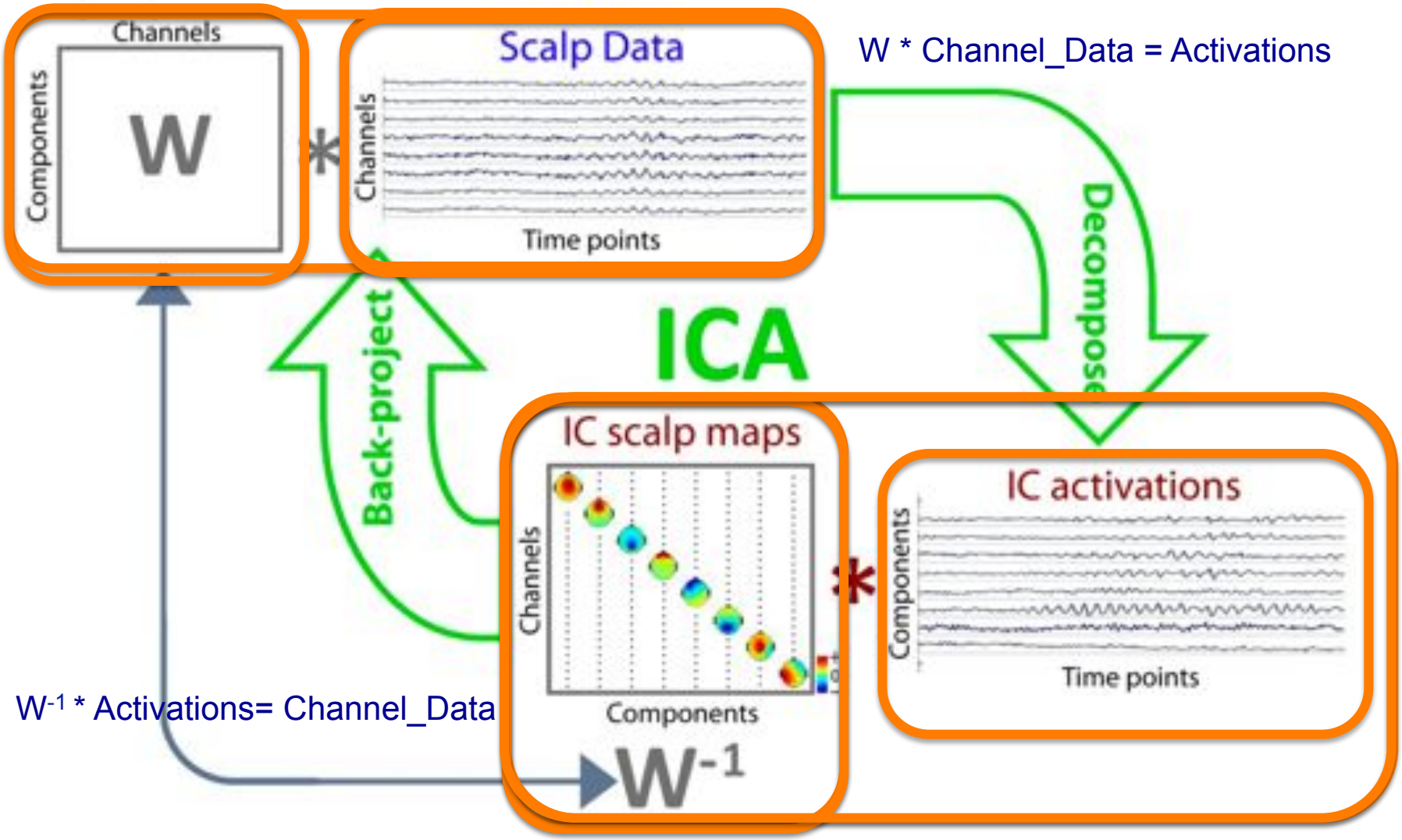
S. Makeig, S. Enghoff (2000)

Are EEG source outputs (near) independent?



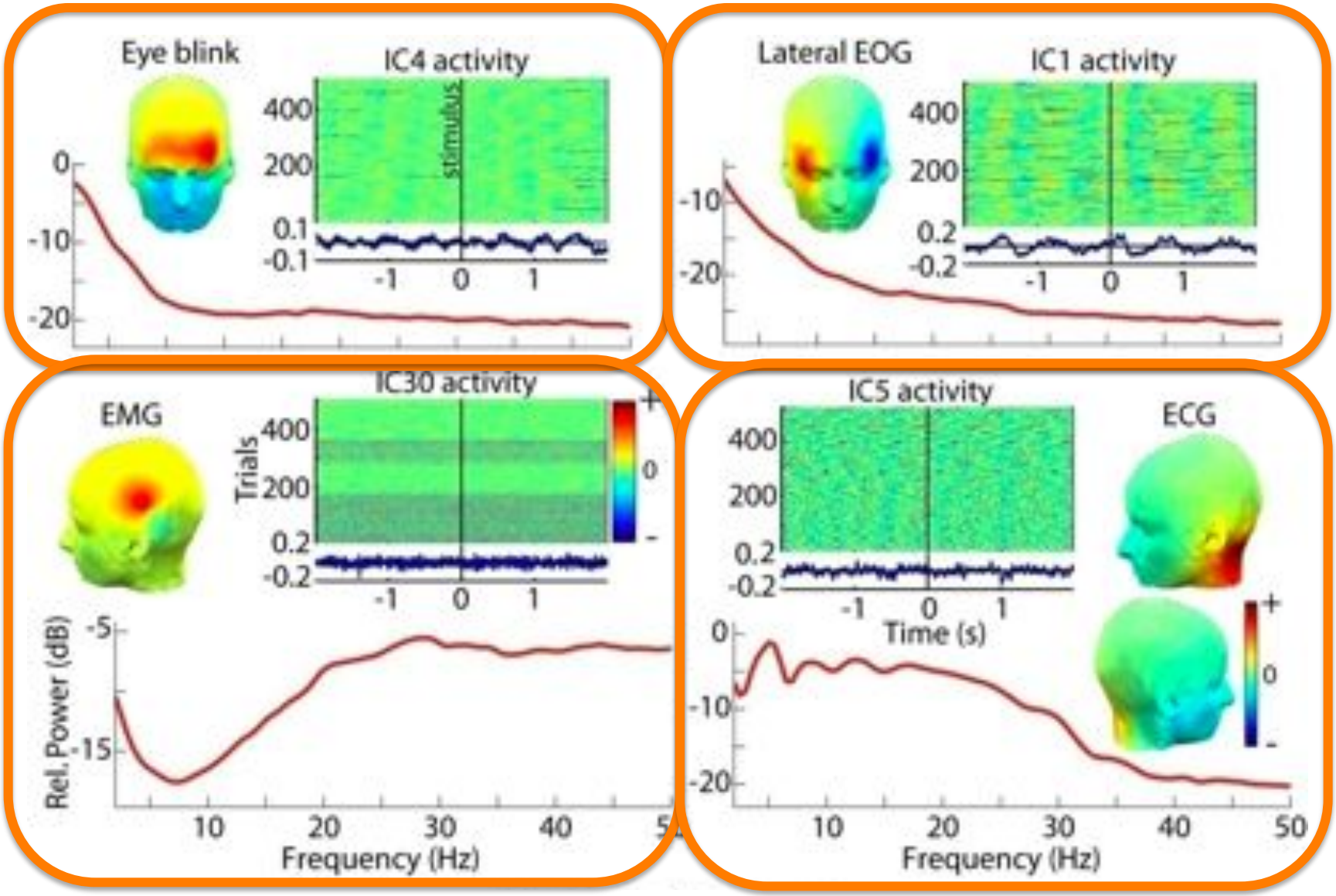
S. Makeig (2007)

ICA is a linear data decomposition method



Makeig & Onton, 2011

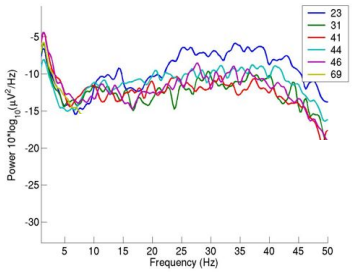
ICA finds Non-Brain Independent Component (IC) Processes …

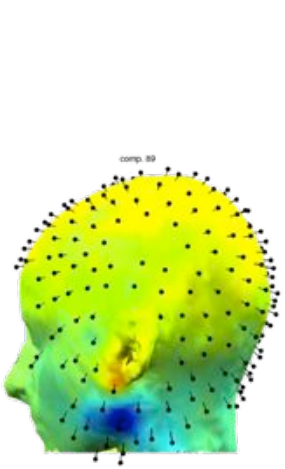


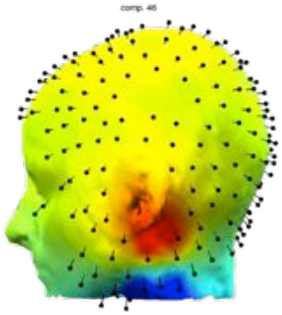
… separates them from the remainder of the data …

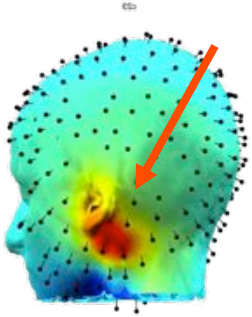
J. Onton & S. Makeig 2006

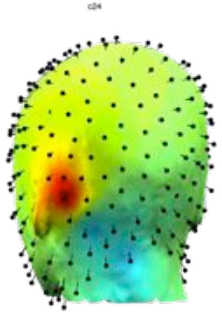
Independent muscle signals

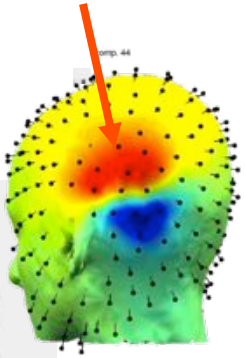


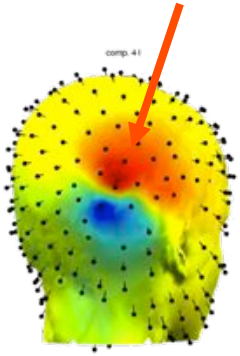


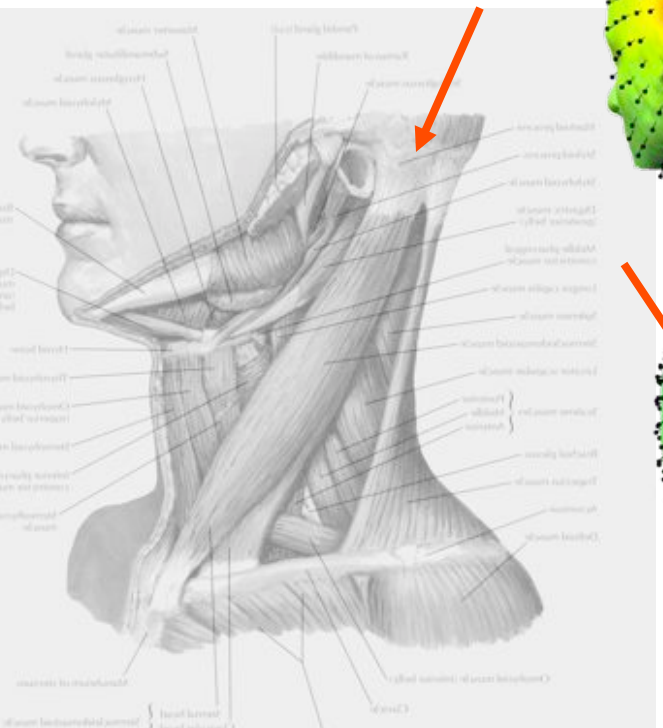


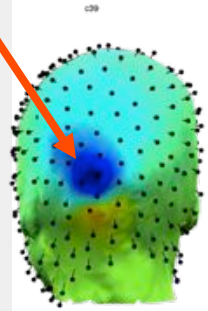


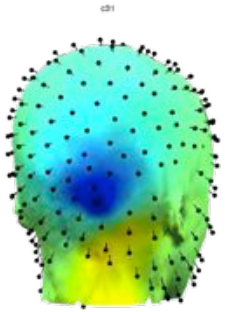


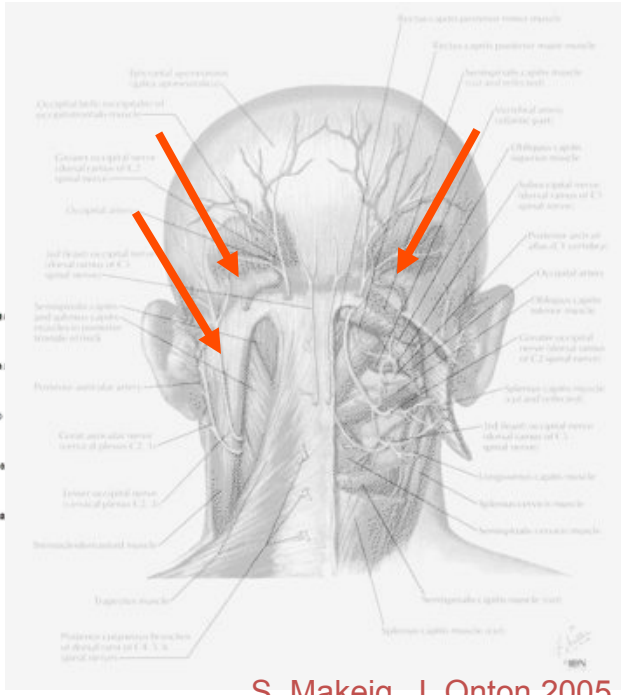






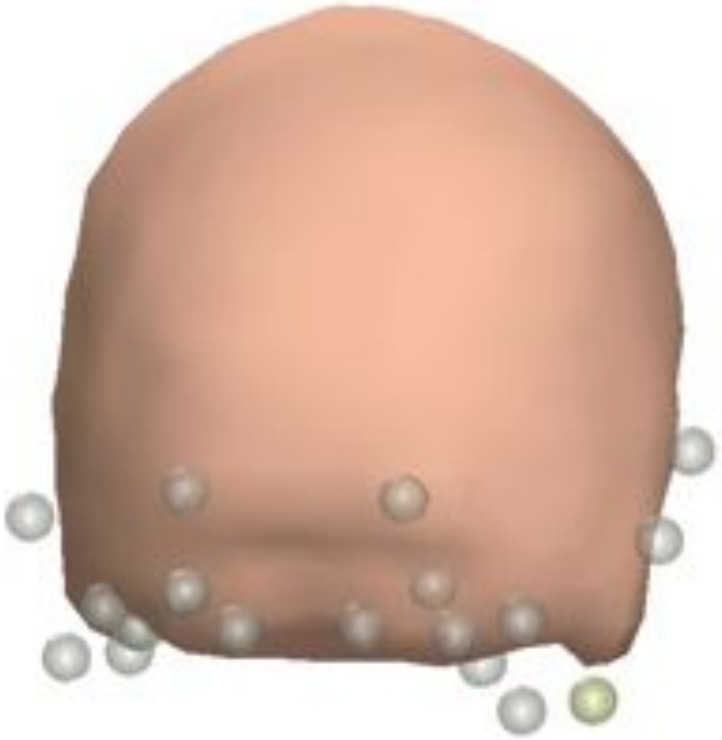


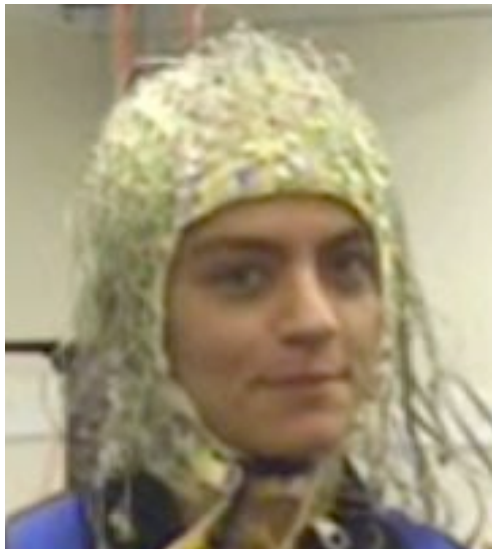


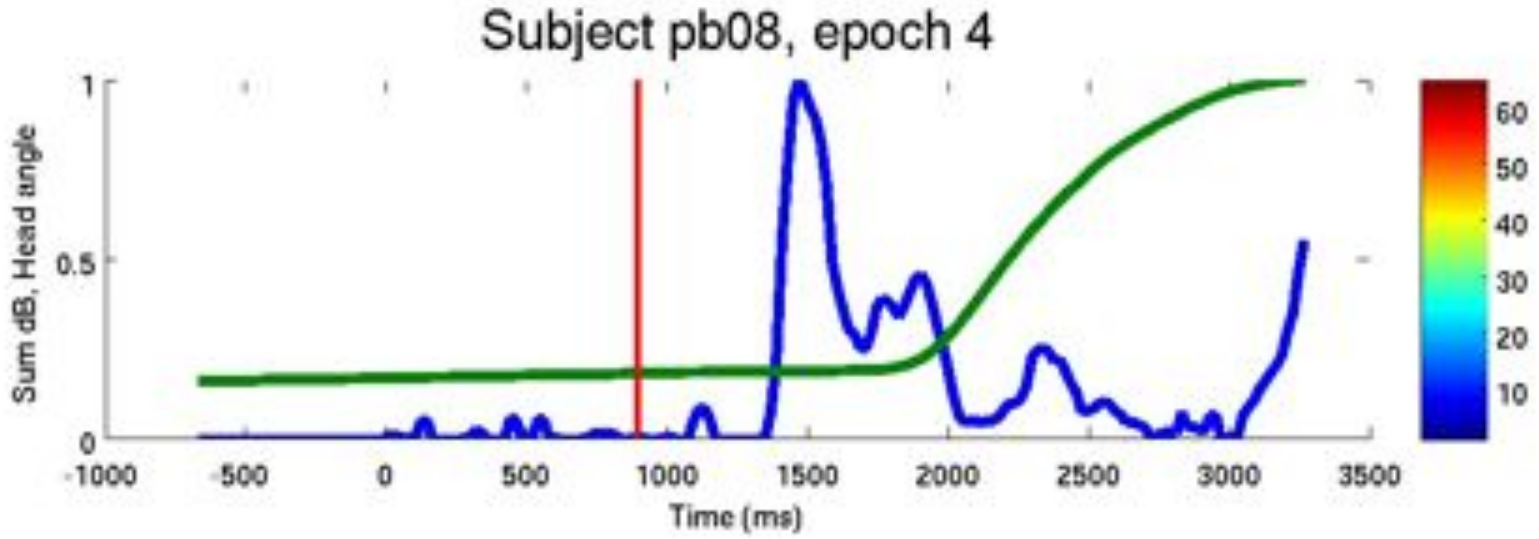


S. Makeig, J. Onton 2005

Distributed neck muscle & movement dynamics

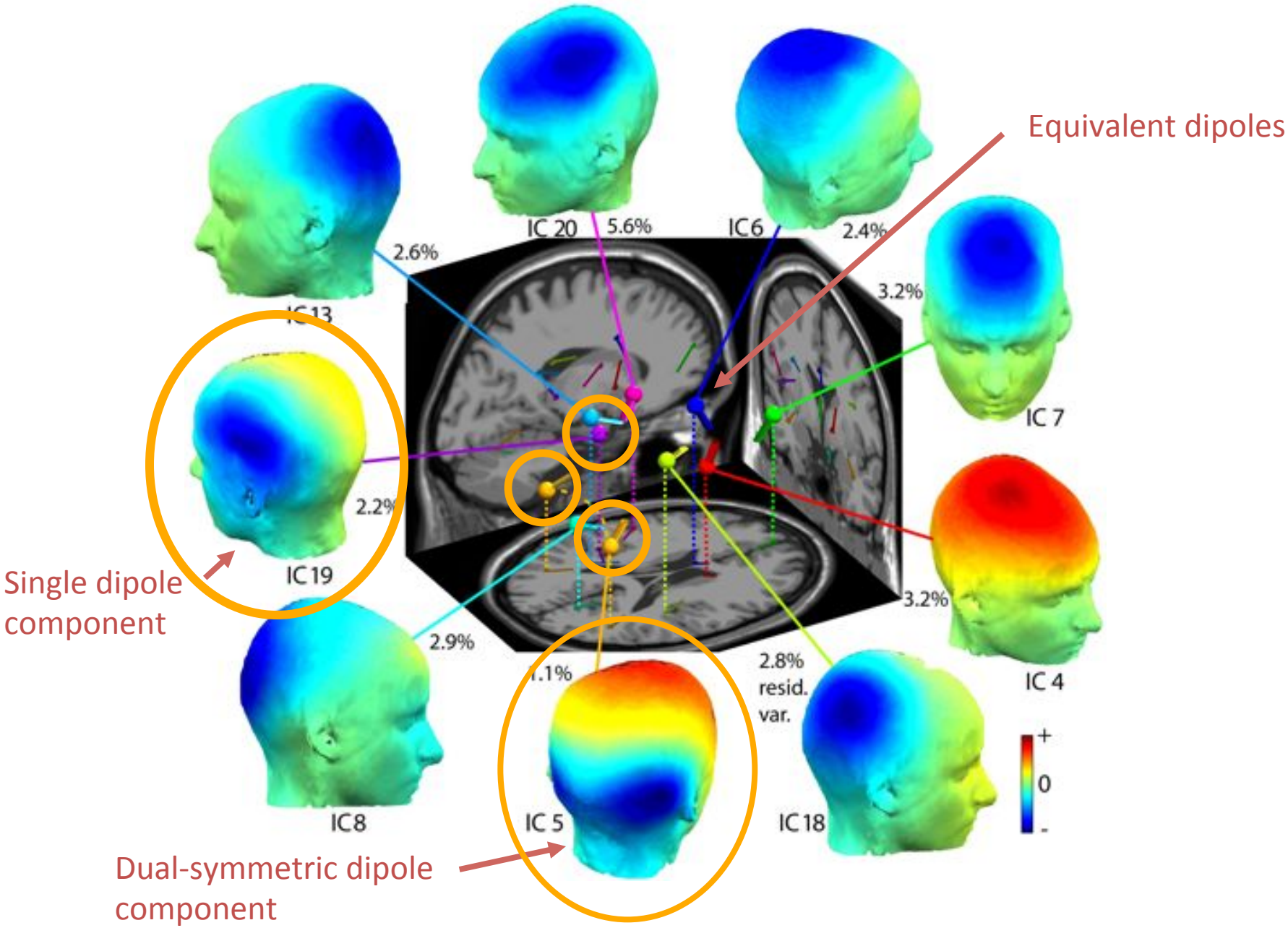




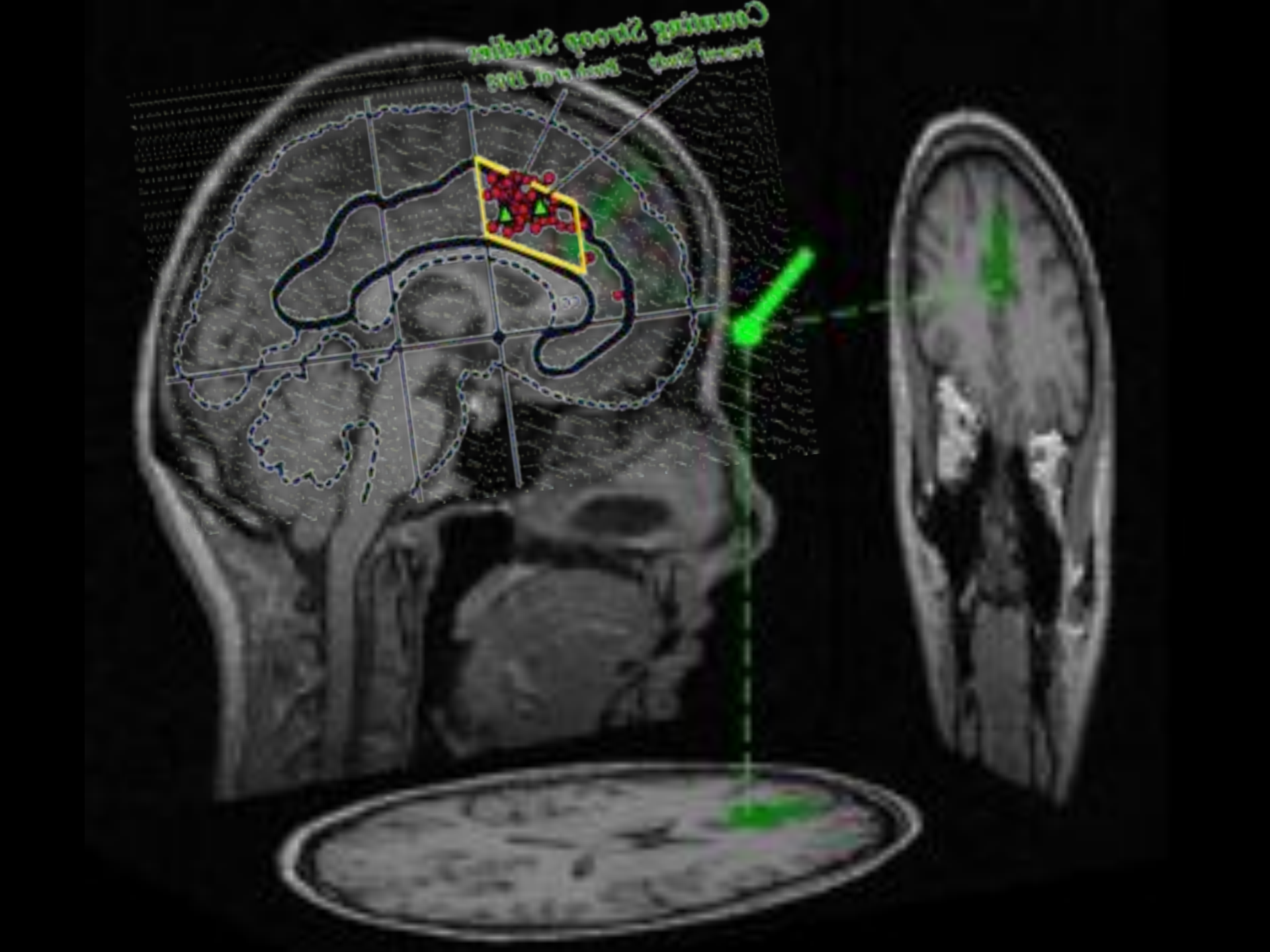


N. Bigdely & S. Makeig, 2009

… and also separates cortical brain IC processes

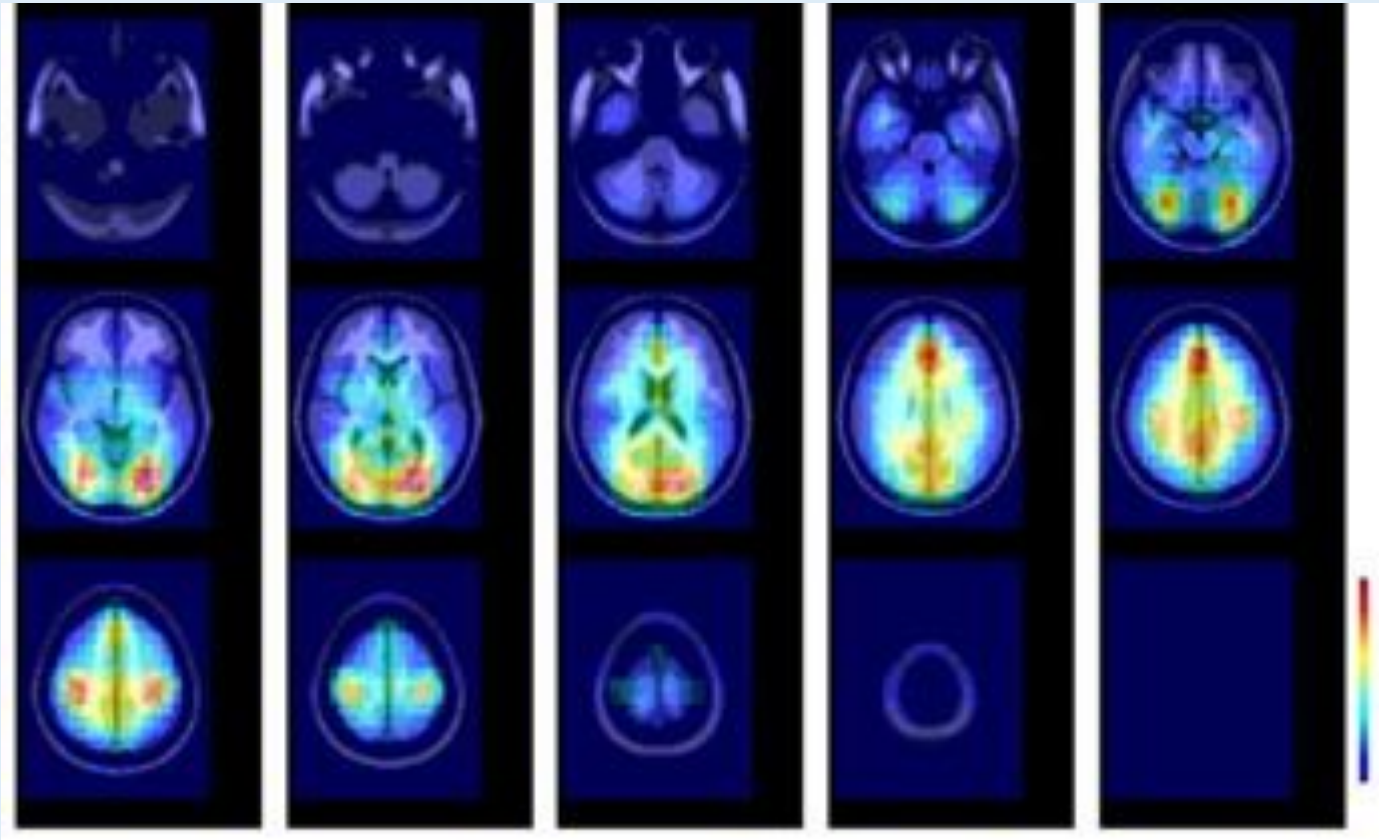


Julie Onton & S. Makeig (2006)



Equivalent dipole density

Visual Working Memory



Sternberg letter memory task

Onton et al., 2005

Onton et al., ‘05

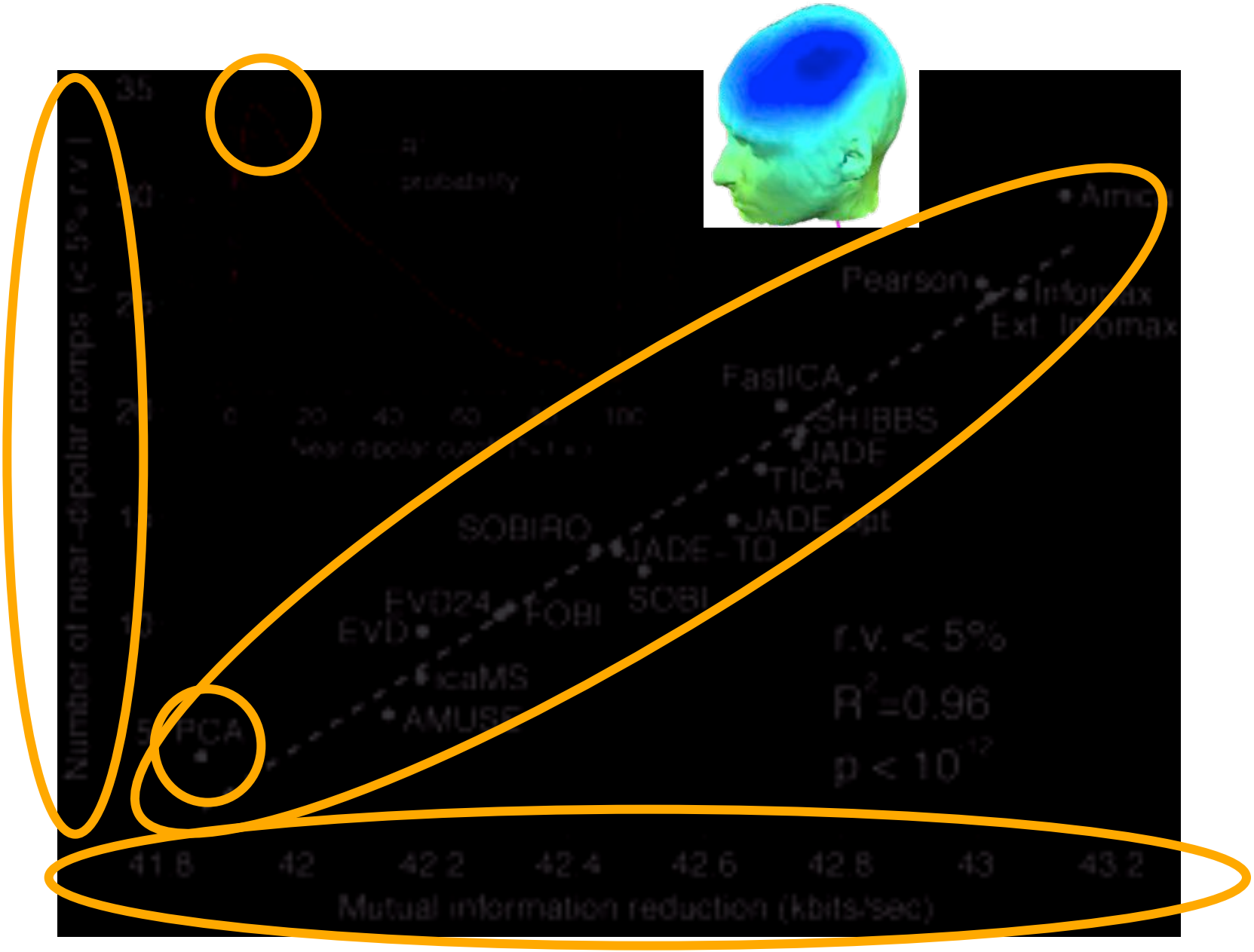
Important Result

Those linear decompositions of multi-channel EEG data that find ICs whose time courses are **more** temporally **independent**

Also find more ICs whose scalp maps are highly **'dipolar'** – i.e., ICs compatible with the spatial projection of a single cortical (or else non-brain, artifactual) source process.

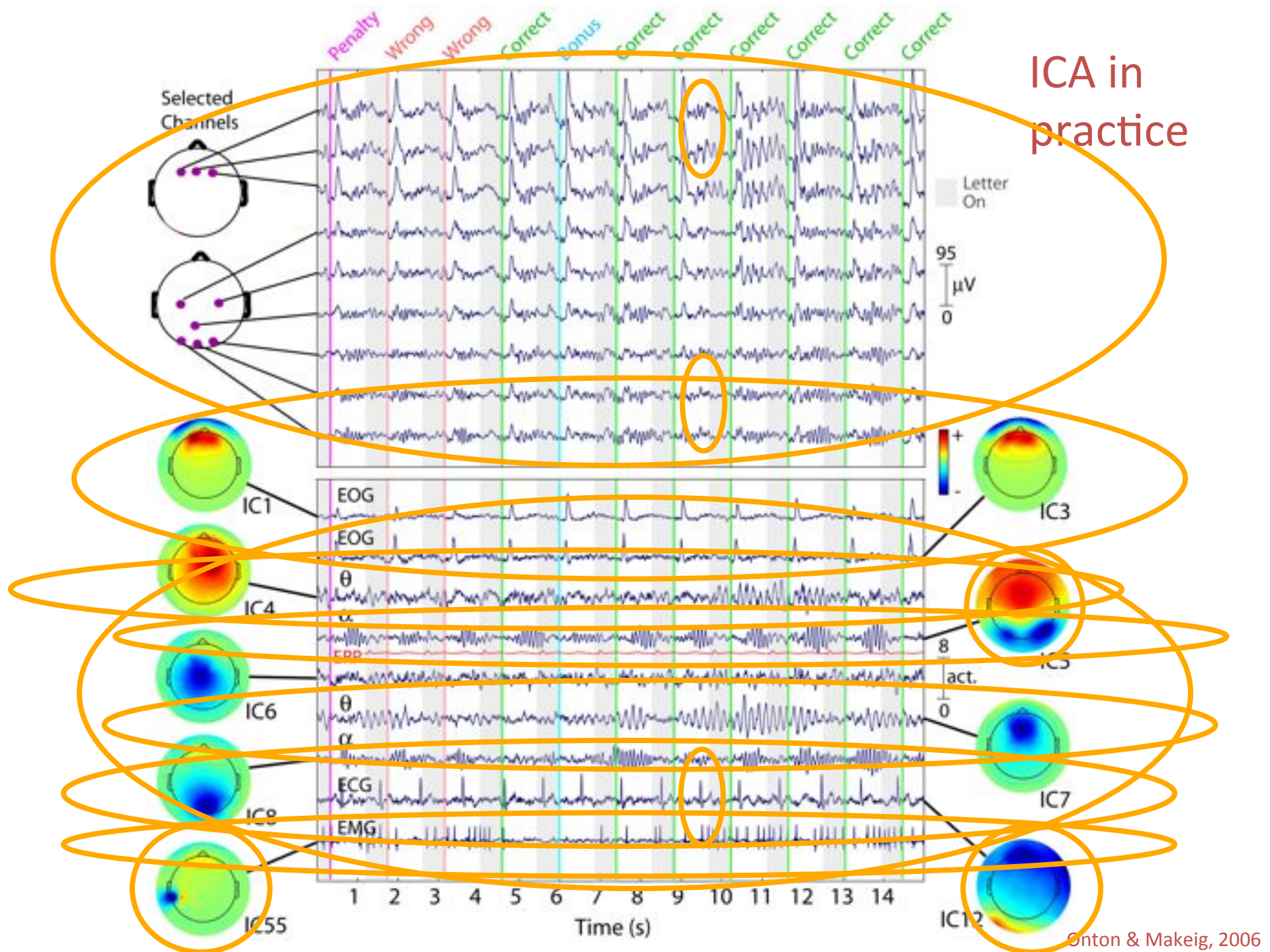
Delorme et al., *PLOS One*, 2012

S. Makeig, 2011

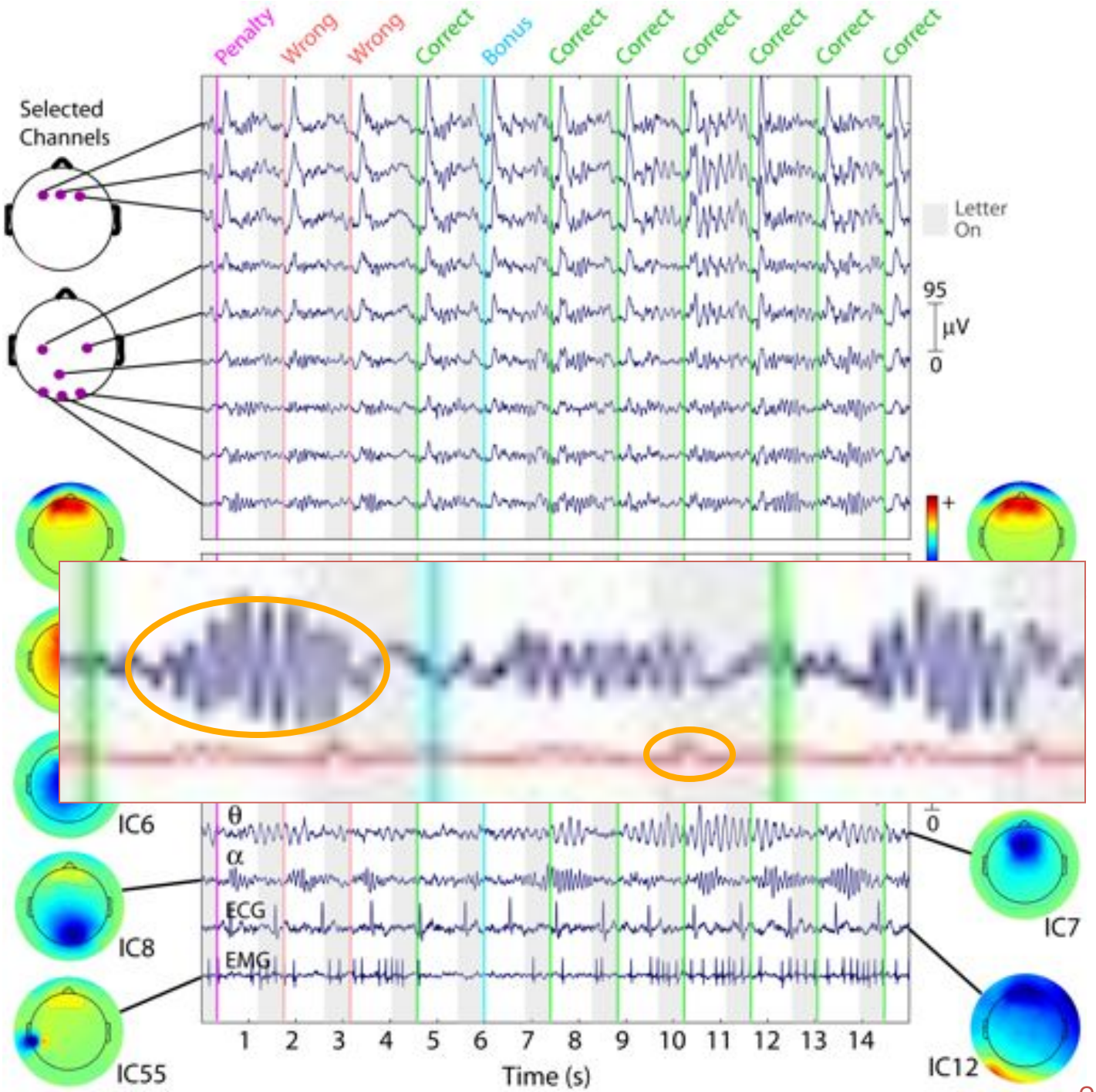


Delorme et al., *PLOS One*, 2012

S. Makeig, 2011

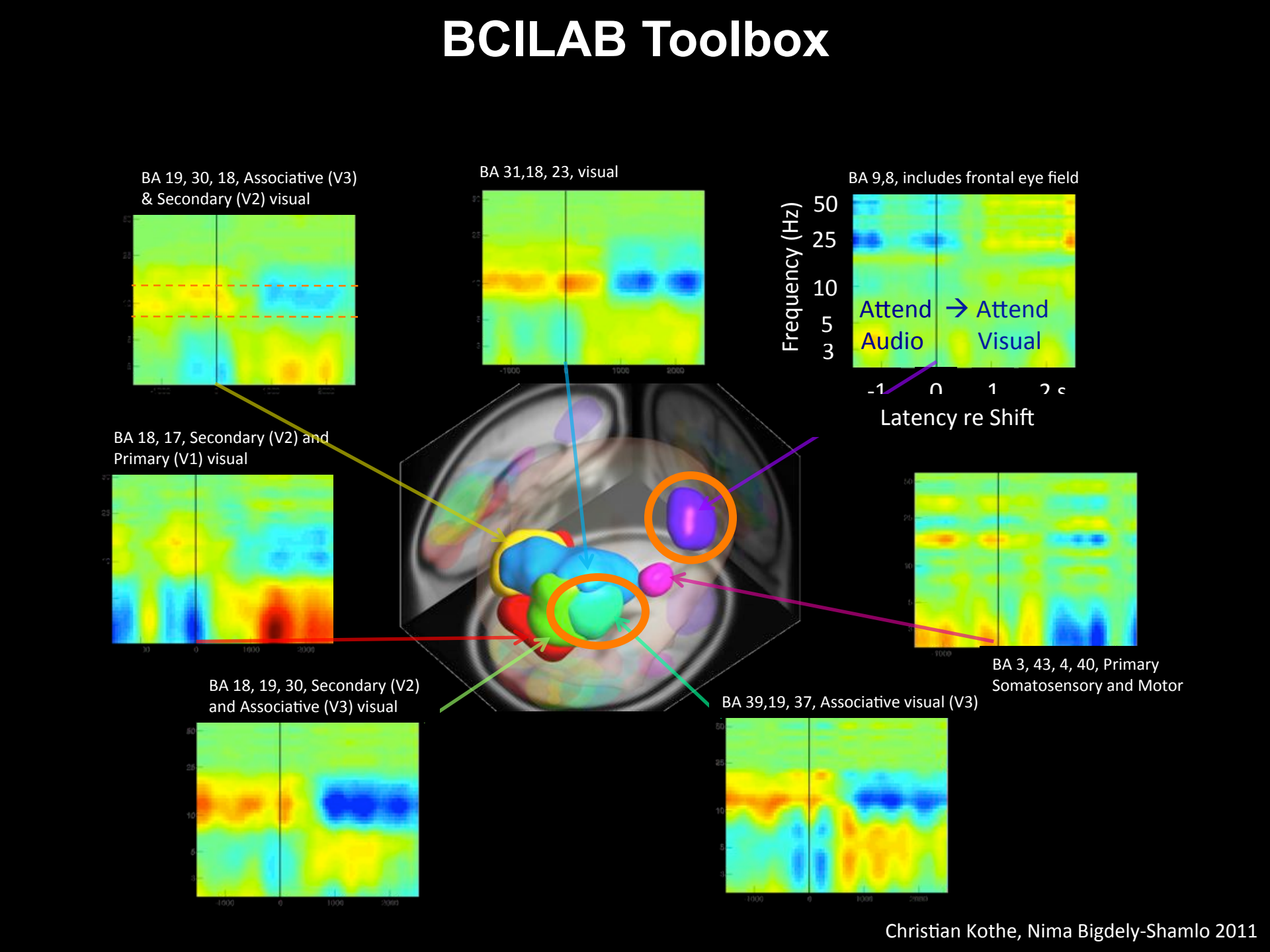


Onton & Makeig, 2006



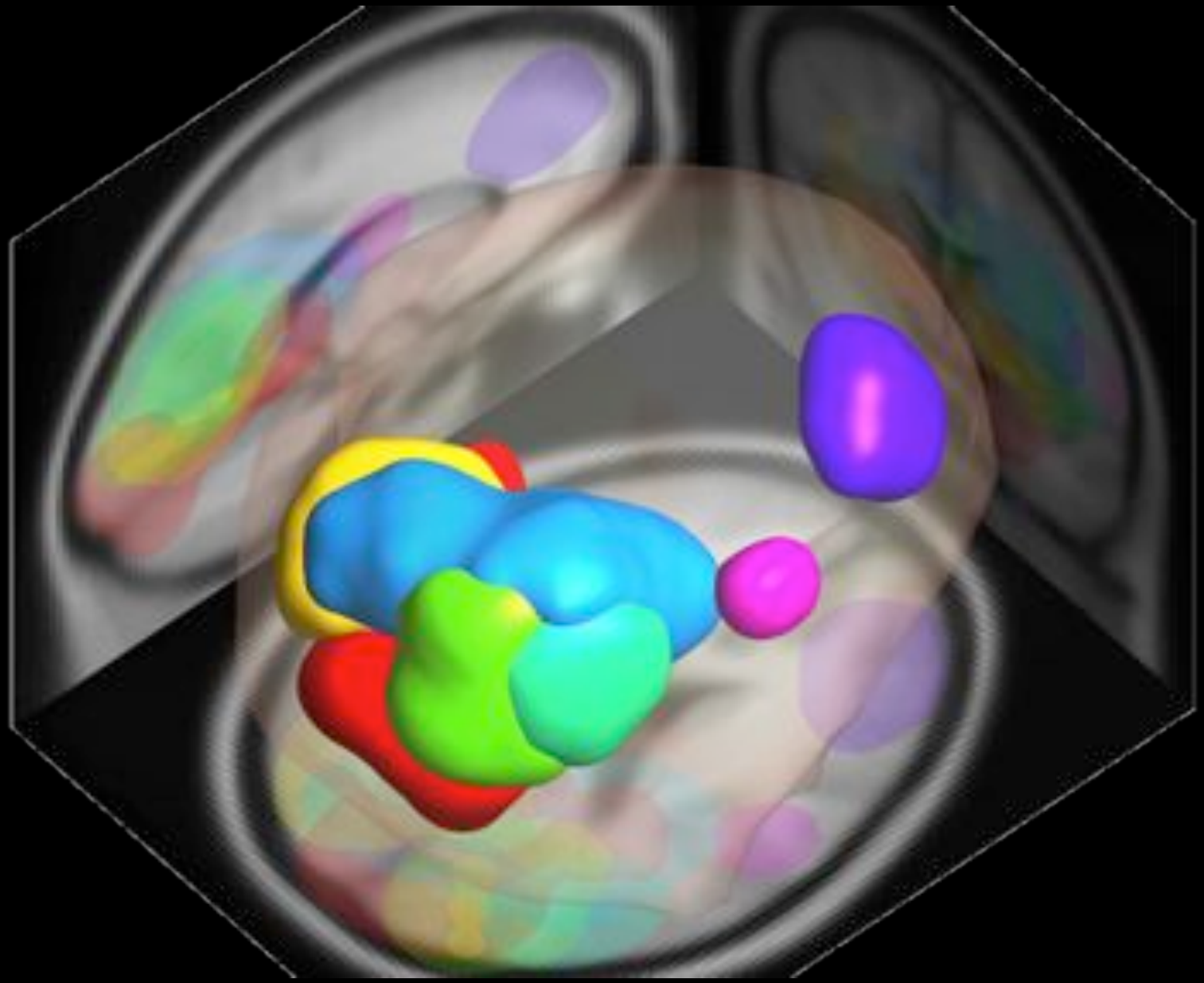
Onton, Makeig (2006)

BCILAB Toolbox



Christian Kothe, Nima Bigdely-Shamlo 2011

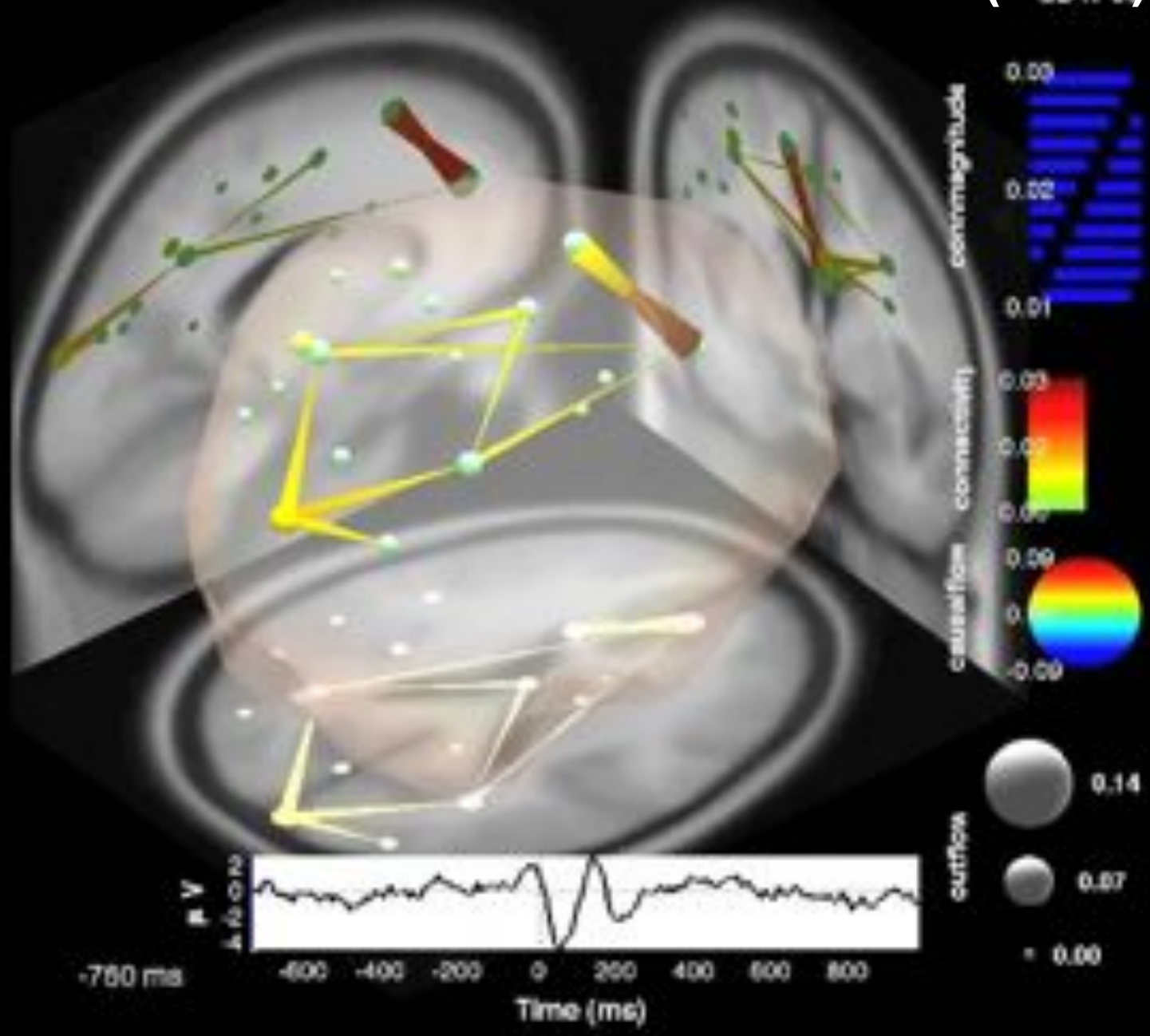
Measure Projection Toolbox (MPT)



(Attn Shift)

Nima Bigdely-Shamlo, 2011

Source Information Flow Toolbox (SIFT)



Tim Mullen, 2011

Questions please!