

Micro-talk session

Introduction

Why is the
brain a critical
and complex
system?

Avalanches
and sleep

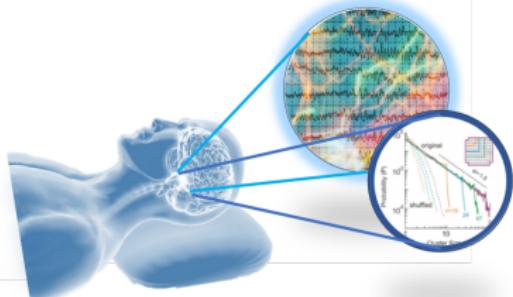
Summary and
future
directions



Computational Neuroscience,
Neurotechnology and Neuro-inspired AI Autumn School

**Study of neuronal avalanches during human
sleep stages to understand brain functioning**

To find sign of criticality in the human brain



Speaker:

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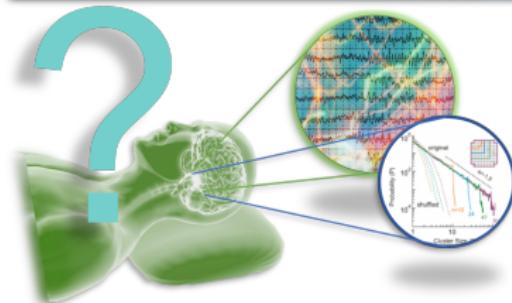
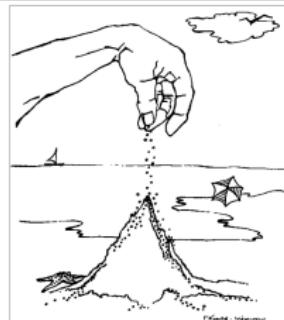
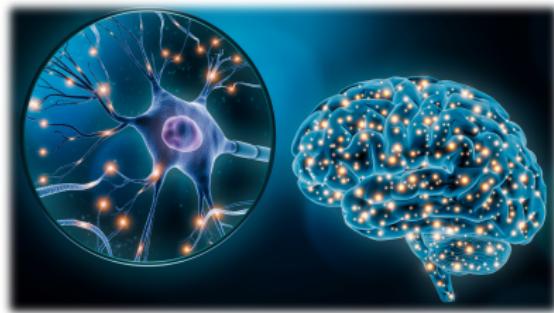
What do these pictures have in common?

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Keywords

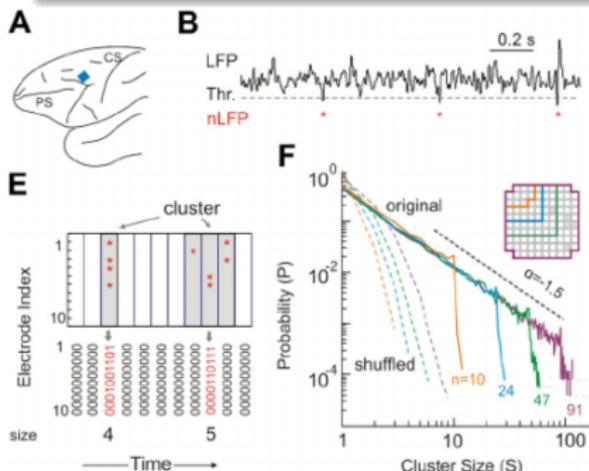
Flock of birds - brain - sandpile model - sleep

Criticality and neuronal avalanches

Feature of a critical behaviour: **scale invariance**

Scale-free property \Leftrightarrow Powerlaw distribution

$p(bx) = g(b)p(x) \quad \forall b \Leftrightarrow p(x) = Cx^{-\alpha}$ where α is the powerlaw exponent, and C is the normalization constant.



Criticality

Criticality refers to the way in which neuronal activity propagates spontaneously

Neuronal avalanche

Clusters of spikes that are preceded and followed by an empty bin.

At critical point

The duration T and size S of avalanches fluctuates over time and their distribution follow a power law, both in-vitro and

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YU, Shan, et al. Higher-order interactions characterized in cortical activity. Journal of neuroscience, 2011, 31.48: 17514-17526.

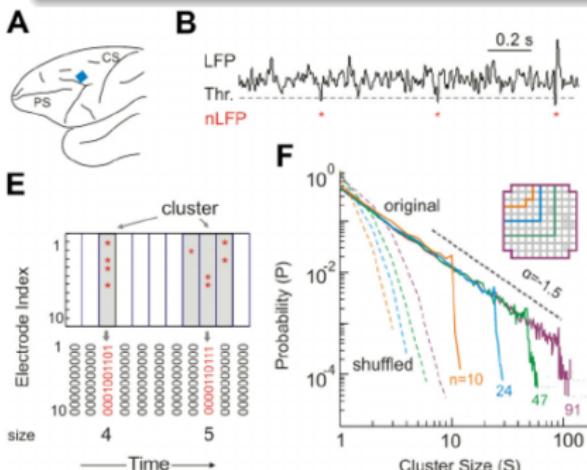
Avalanche size (S)=the number of spikes

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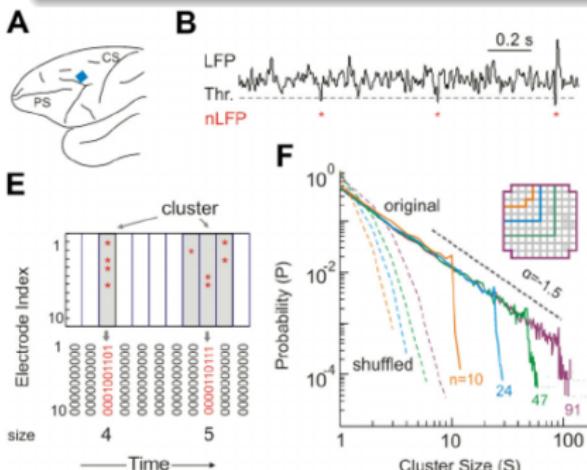
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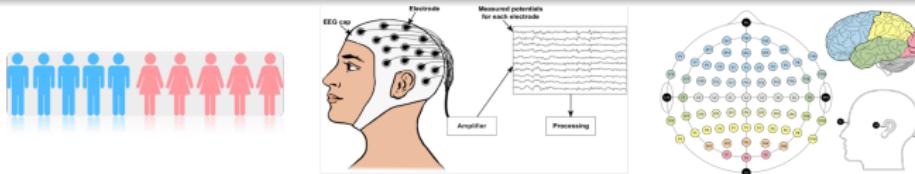
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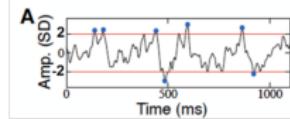
Neuronal activity during the sleep-wake cycle

Data

EEG recordings of **10 healthy (without any psychiatric, medical and neurological disorder) subjects** - *Sleep Disorders Center database*, University of Parma.



Neural avalanche
a continuous sequence of signal excursions beyond threshold (red thick line) on one or more EEG channels



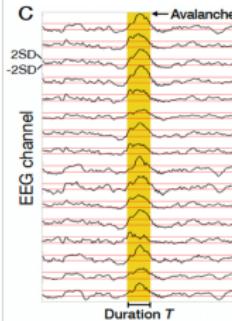
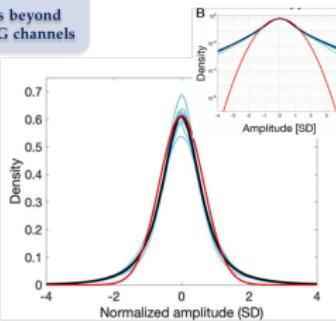
Probability density of the normalized EEG signal amplitude.

The cyan curves are the probability densities for all individual subjects.

The black curve is the grand average over all subjects.

The red curve is the best Gaussian fit for the grand average.

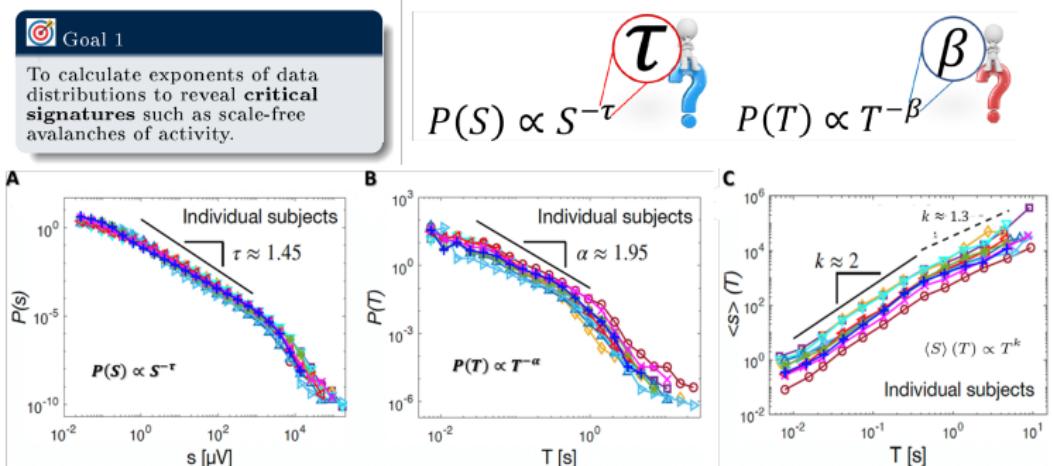
We notice that the empirical probability density starts deviating from the Gaussian fit around $\hat{\sigma} > 2 \text{ SD}$



$$\text{Size : } s = \sum_{n=1}^{\# \text{channels}}$$

Goal 1

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Sethna's Scaling relation is satisfied!

$$k = \frac{\alpha - 1}{\tau - 1} = 2.13 \pm 0.25 \text{ (mean } \pm \text{sterr)}$$

Exponents in agreement with branching process

$$(\text{MF-DP} : \tau = \frac{3}{2}; \alpha = 2; k = 2)$$

Goal 2

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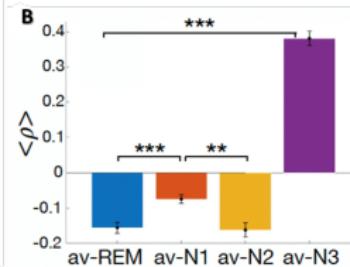
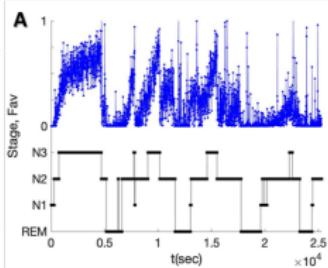
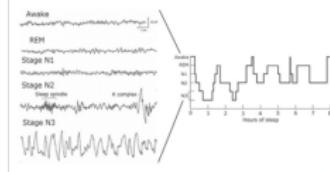
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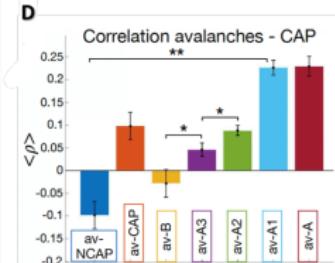
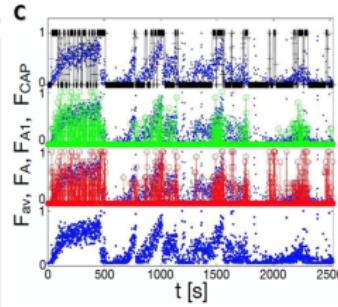
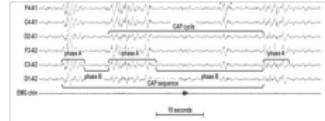
Goal 2.1

To evaluate the *Pearson correlation coefficient* between the avalanche occurrence and the presence of a particular sleep stage.



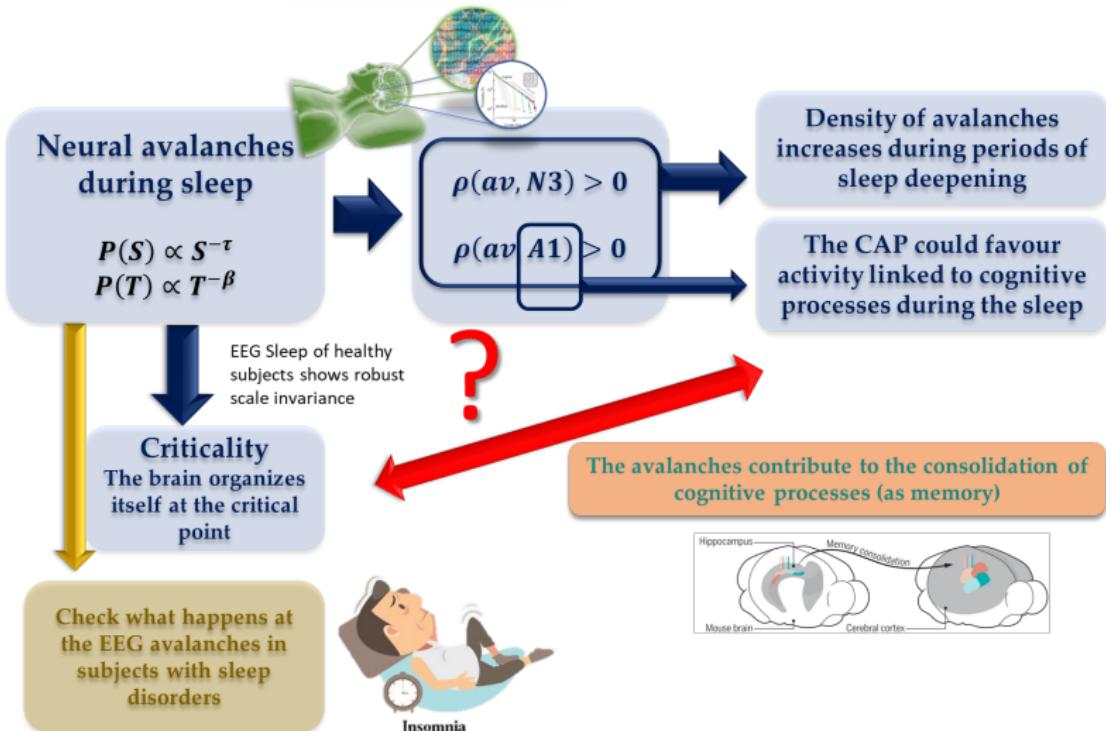
Goal 2.2

To evaluate the *Pearson correlation coefficient* between the avalanche occurrence and microstructure features.



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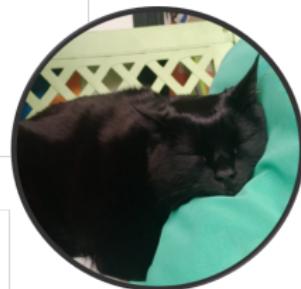
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thanks
FOR YOUR ATTENTION



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Criticality of neuronal avalanches in human sleep and their relationship with sleep macro- and micro-architecture

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