Optimal Strategy to Sample Complex Systems

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Supervisor: Matteo Marsili
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Personal Background

- 2006-2012: Degree in Physics at the Universidad de Buenos Aires, Buenos Aires, Argentina.

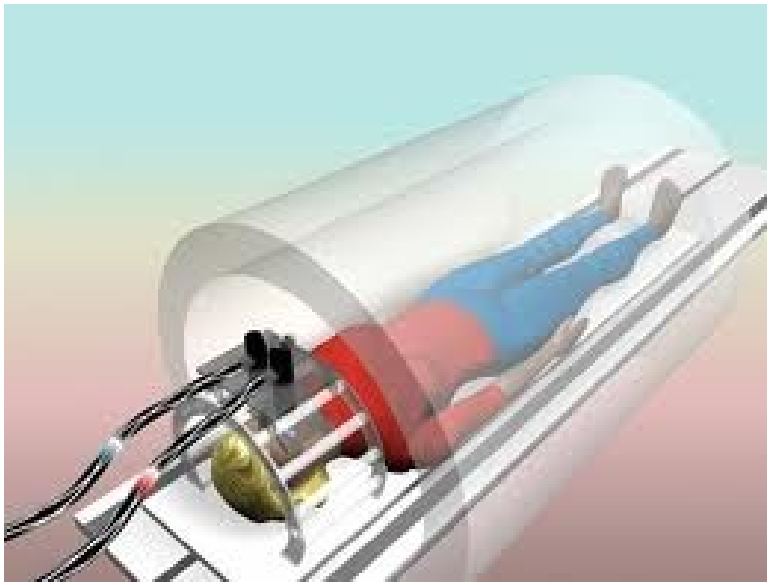
  Degree Thesis: “Study of the spontaneous fluctuations of large scale brain activity”
  Supervisors: Dr. Dante R. Chialvo, Dr. Pablo Balenzuela.
  [Haimovici et al 2013]

- 2012-Present: phd student at Universidad de Buenos Aires.
  Supervisor: Dr. Dante R. Chialvo
  Courses:
  - Non Linear Dynamics. Dr G Mindlin
  - Computational Neuroscience. Dr M Sigman
  - Complex Networks. Dr H Makse
  - Computational tools in Neuroscience. Dr M Isson

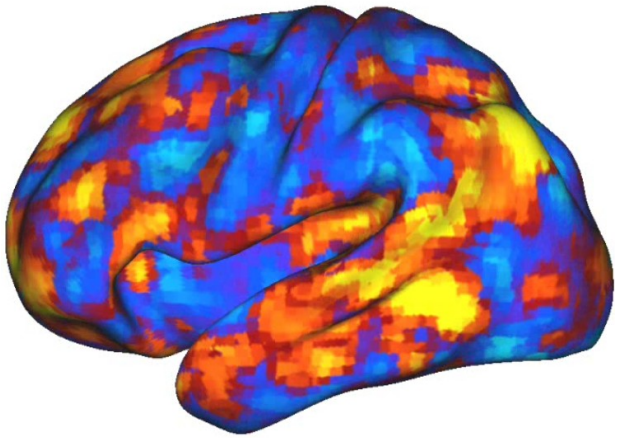
- July-2013: “School on Biological Complex Networks: from the cell to the brain and beyond”, Natal, Brasil. Orginizers: Drs. JM Buldú, S Boccaletti, H Herrmann, J Soares Andrade, L Da Silva.

- **November 2013 – Present**: ESR in Netadis, at the ICTP, Trieste, Italy.
  - Course on Advanced Probability Theory. Dr Matteo Marsili, SISSA, Trieste.

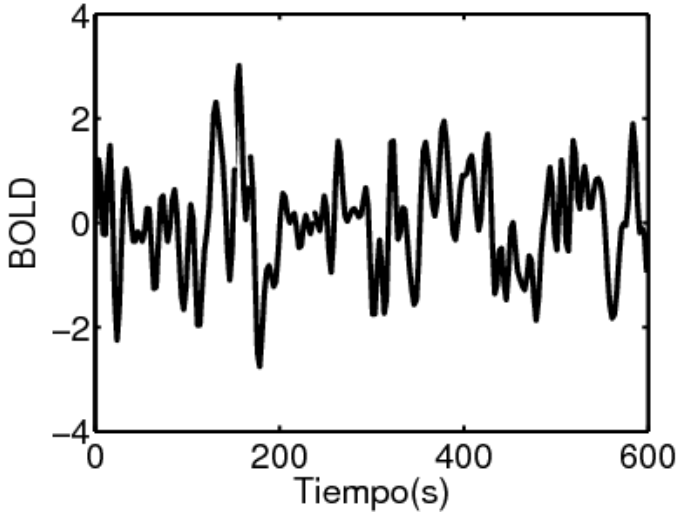
Phd Project: unraveling large scale brain dynamics

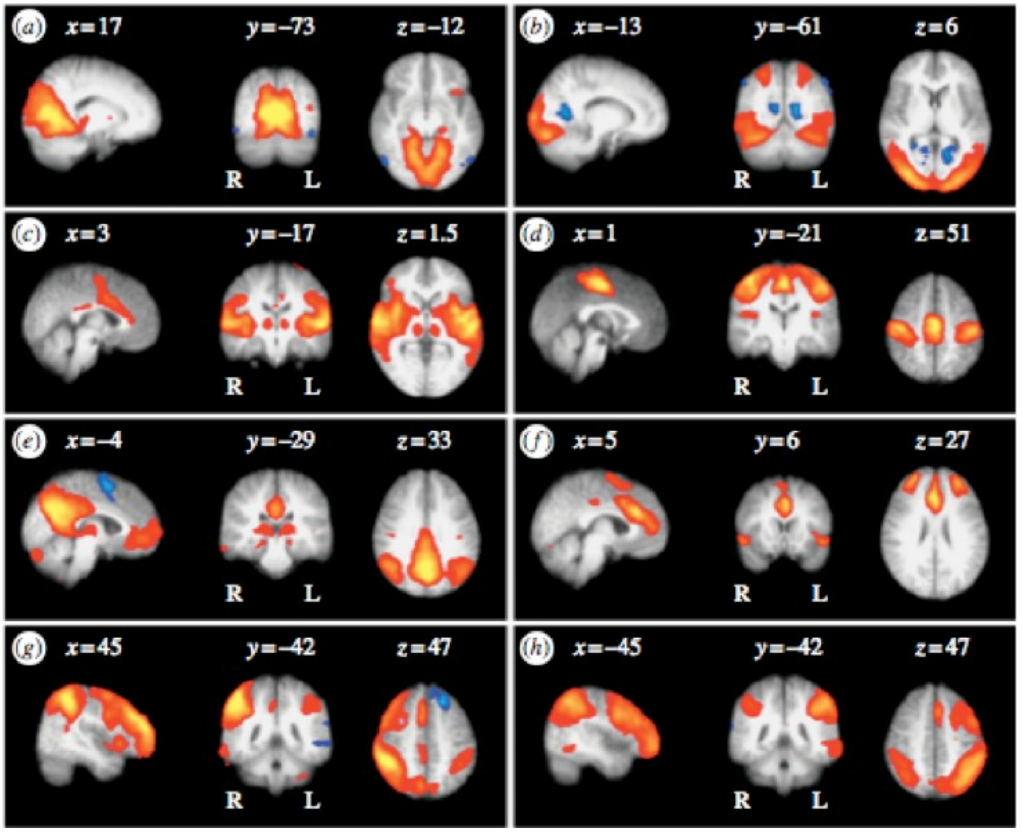


Functional Magnetic Resonance Imaging



40000 Time series of ~ 300 points





[Beckman et al 2005]

How is the exploration of the *phase space*?

Current project within NETADIS

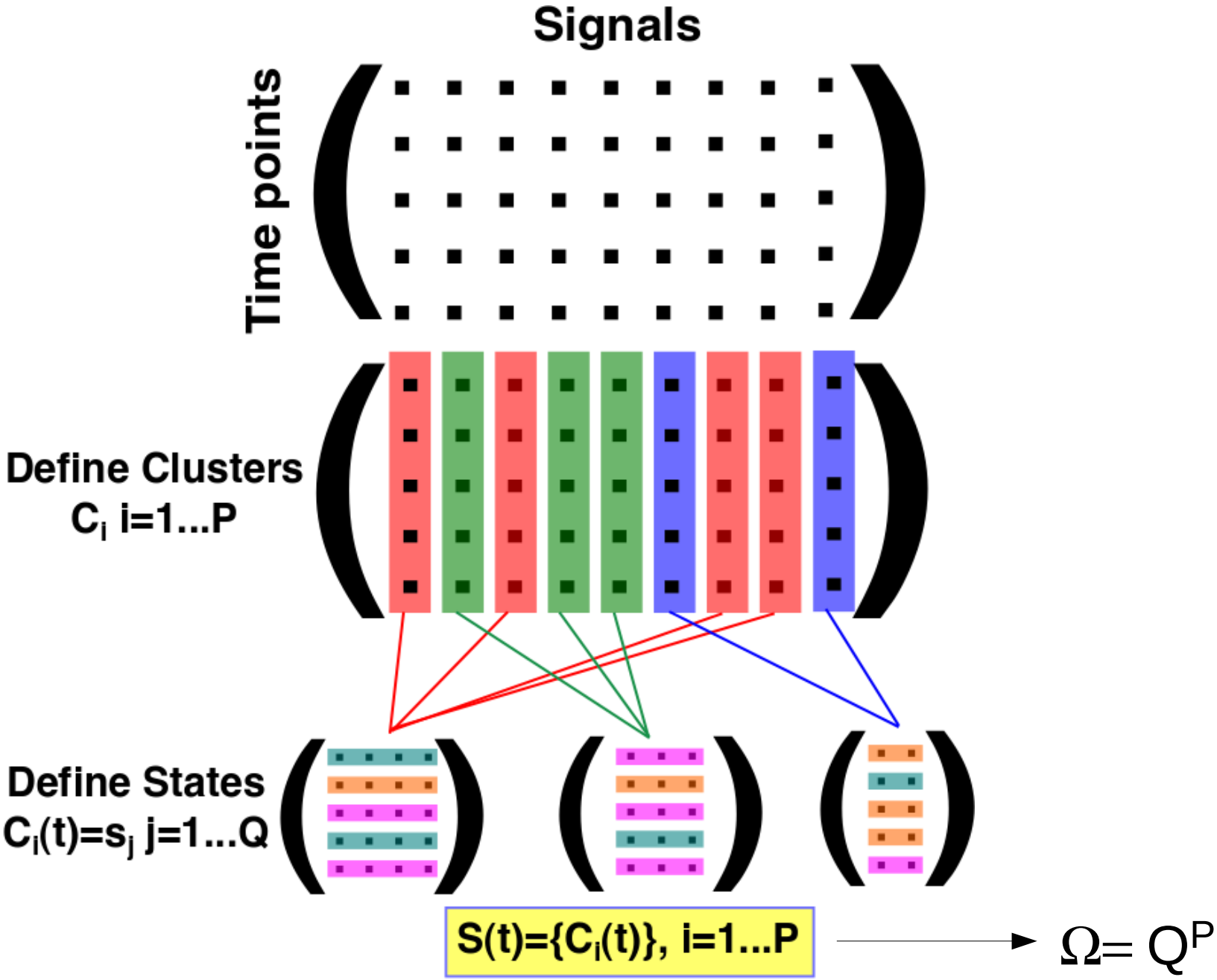
- Find informative representations of the system's dynamics

  Clustering techniques to reduce the systems dimensionality in an *optimal* manner

- Infer the interactions between the systems constituents.

  How does information flow in the brain?

How are we doing it



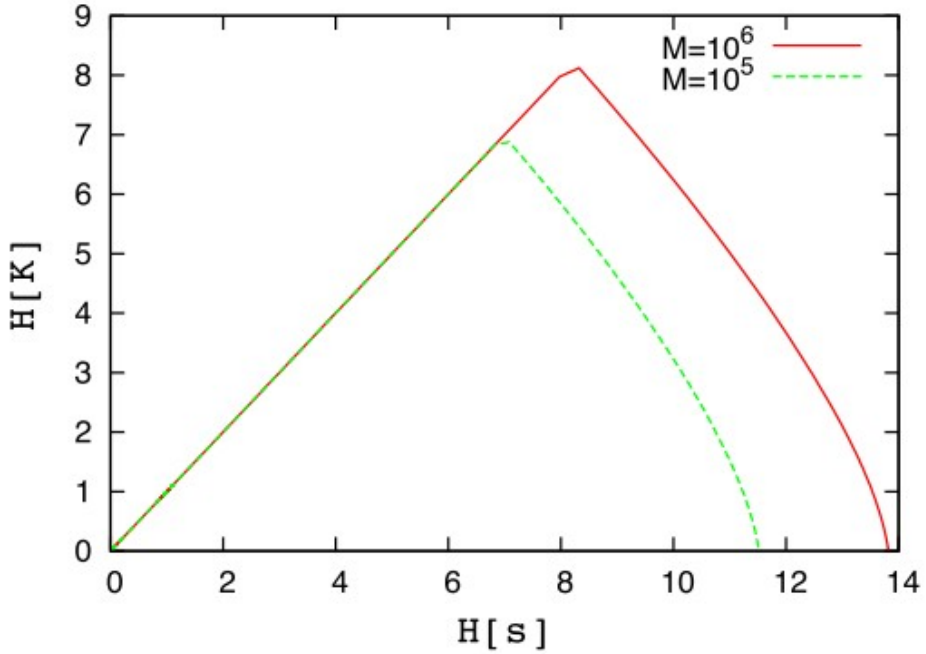
How to choose the optimal resolution

Given the distribution of system's states (S), and state's frequencies (K), compute the entropy of the frequencies H[K] as a measure of the information content.
[Marsili et al 2013]

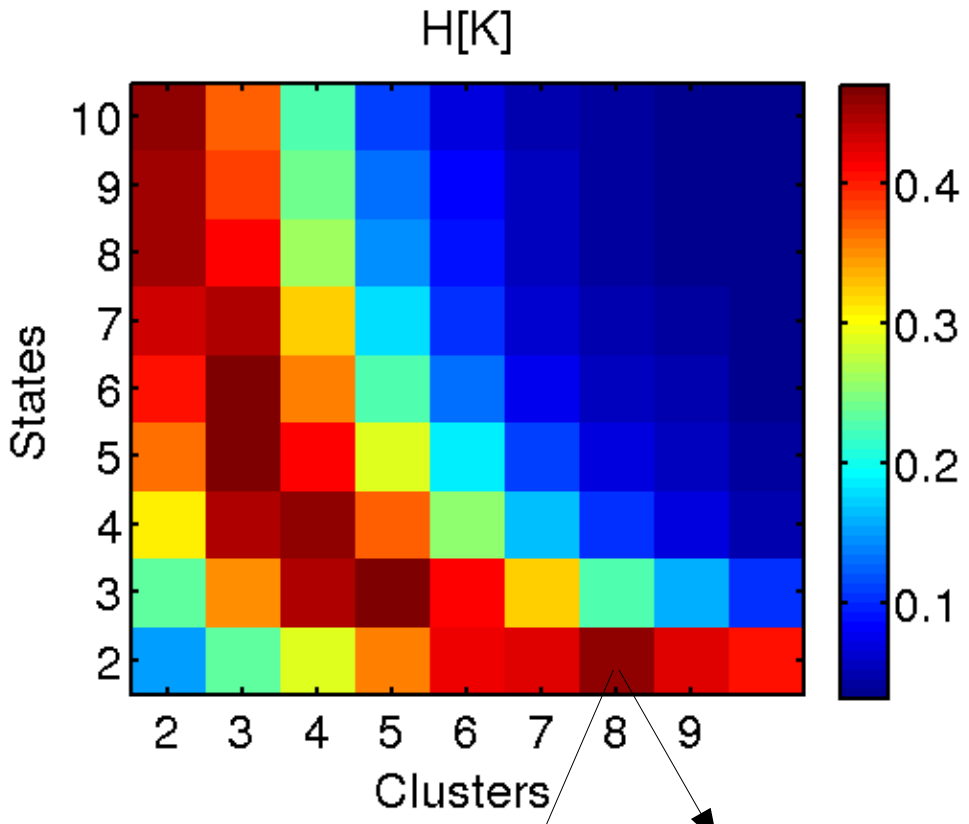
If there are mk states (S) which are observed k times, in a sample of M points:

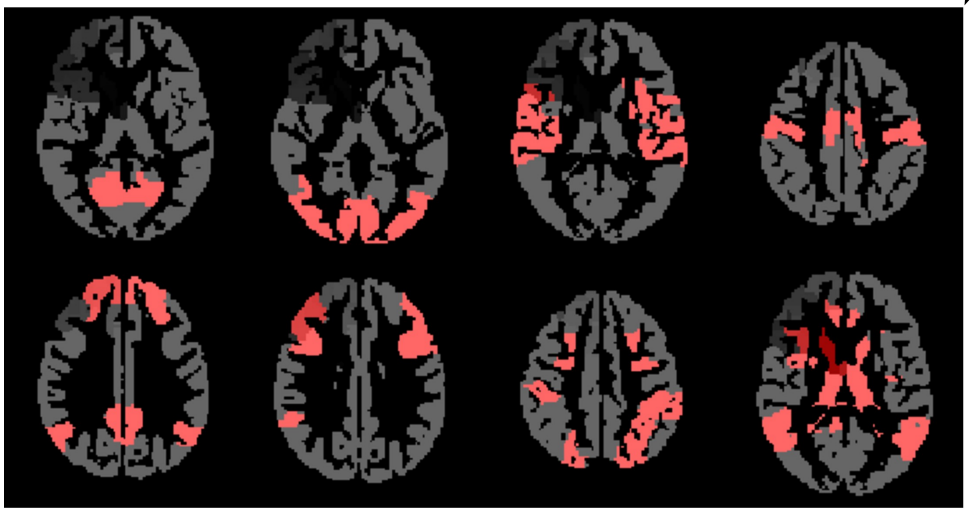
$$\hat{H}[\underline{s}] = -\sum_{\underline{s}} \hat{p}_{\underline{s}} \log \hat{p}_{\underline{s}} = -\sum_{k} \frac{k m_k}{M} \log \frac{k}{M}$$

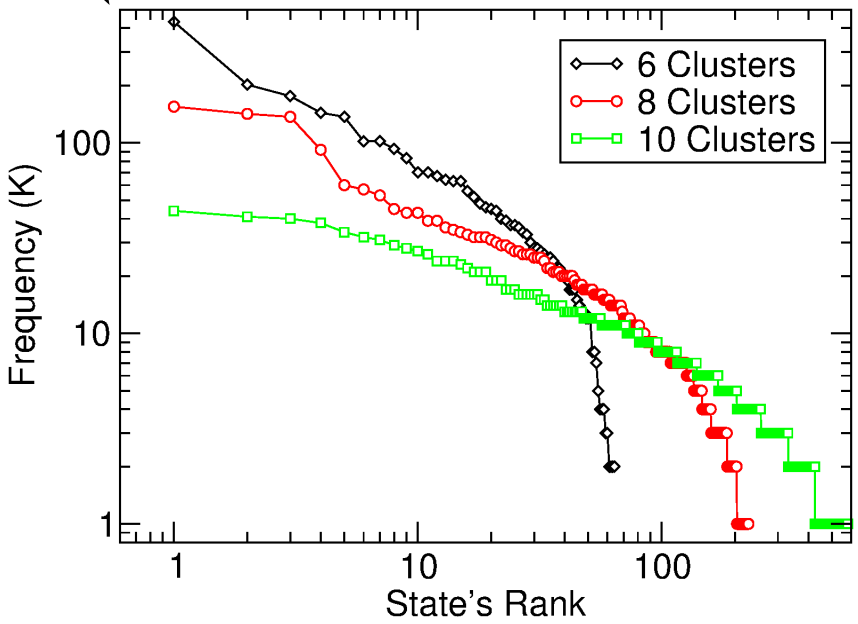
$$\hat{H}[K] = -\sum_{k} \frac{k m_k}{M} \log \frac{k m_k}{M} = \hat{H}[\underline{s}] - \sum_{k} \frac{k m_k}{M} \log m_k$$



Back to the Brain







Short term future

- Inference on the system's dynamics
- Apply this type of analysis to an fMRI experiment in which the subjects perform a specific cognitive task. In collaboration with Drs A. Laio and D. Amati (SISSA, Trieste).
- Apply this type of analysis to financial data. [Marsili 2008]

Thank you

References:

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