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BOOK OF ABSTRACT

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#603 - Correlations in brain activity

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Neuronal avalanches are a novel mode of spontaneous brain activity, experimentally found *in vitro* and *in vivo,* which exhibits a robust critical behaviour. Avalanche activity can be modelled within the self-organized criticality framework, including threshold firing, refractory period and activity-dependent synaptic plasticity. The size and duration distributions confirm that the system acts in a critical state, whose scaling behaviour is in agreement with experimental data. Interestingly, the critical behaviour is robust with respect to network features but shows interesting features on modular networks.
The temporal organization of neuronal avalanches can be characterized by the distribution of waiting times between successive events. Experimental measurements in the rat cortex in vitro exhibit a non-monotonic behavior, not usually found in other natural processes. Numerical simulations provide evidence that this behavior is a consequence of the alternation between states of high and low activity, leading to a dynamic balance between excitation and inhibition. This behavior has been verified on a larger scale, i.e., on fMRI data from resting patients, where activity variations with opposite sign are correlated over a temporal scale of few seconds, suggesting a critical balance between activity excitation and depression in the brain.

#604 - A novel view of brain function: emergent neural dynamics near criticality

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A large repertoire of spatiotemporal activity patterns in the brain is the basis for adaptive behaviour. Understanding the mechanism by which the brain's hundred billion neurons and hundred trillion synapses manage to produce such a range of cortical configurations in a flexible manner remains a fundamental problem in neuroscience. One plausible solution is the involvement of universal mechanisms of emergent complex phenomena evident in dynamical systems poised near a critical point of a second-order phase transition. We review recent theoretical and empirical results supporting the notion that the brain is naturally poised near criticality, as well as its implications for better understanding of the brain.

#605 - Self-organized criticality in cortical ensembles is promoted by concurrent scale-free and small-world networks

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The spontaneous activity of cortical networks is characterized by the emergence of different dynamic states. Although several attempts were accomplished to understand the origin of these dynamics, the underlying factors continue to be elusive. In this work, we specifically investigated the interplay between network topology and spontaneous dynamics within the framework of self-organized criticality (SOC). The obtained results support the hypothesis that the emergence of *critical states* occurs in specific complex network topologies. By combining multi-electrode recordings of spontaneous activity of *in vitro* cortical ensembles with theoretical models, we demonstrate that different 'connectivity rules' drive the network towards different dynamic states. In particular, scale-free architectures with different degree of small-worldness account better for the variability observed in experimental data, giving rise to different dynamic states.

Keywords: connectivity, cortical assemblies, neuronal avalanches, self-organized criticality, simulations

#606 - Looking into the architecture of the brain with MRI: quantification of non-Gaussian water diffusion by Diffusion Kurtosis Imaging (DKI)

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The analysis of diffusion tensor imaging (DTI) allows to evaluate *in vivo* and in a non-invasive way the process of diffusion of water molecules in biological tissues. The peculiar organization of some biological tissues influences this phenomenon making it anisotropic and therefore well evaluable with these techniques. Changes in tissue anisotropy can also be found in many diseases without any signal intensity variation on conventional MR pulse sequences since they are intimately related to intrinsic micro-structural changes.
Despite all these important applications, DTI fails to fully utilize the MR diffusion measurements that are inherent to tissue microstructure. DTI implicitly assumes that water molecule diffusion occurs with a Gaussian distribution of diffusion displacement. This assumption has been experimentally demonstrated to be not always suitable in both white matter and gray matter. Moreover,

the simplified description of the diffusion process *in vivo* by a 2nd-order 3D diffusion tensor prevents DTI from being truly effective in characterizing relatively isotropic tissue such as GM. Even in WM, the DTI model can fail if the tissue contains substantial crossing or diverging fibers.
Jensen et al. introduced diffusion kurtosis imaging (DKI), a higher order diffusion model that is a straightforward extension of the DTI model. DKI is an approximation of the logarithmic expansion of the DWI signal decay up to the b^2 term and neglects the b^3 terms. DKI gives a dimensionless measure that quantifies the deviation of the water diffusion displacement profile from the Gaussian distribution of unrestricted diffusion, providing a measure of the degree of diffusion hindrance or restriction.
The aim of this work is the definition of an MRI protocol for Diffusion Kurtosis Imaging (DKI) by using a 1.5T clinical scanner and the development of a software for DKI analysis.
Indeed, the extensive application of DKI in a clinical routine must deal with several difficulties. The most important is the long acquisition time. In clinical applications the real issues is to find a good compromise between acquisition time and robustness of the fit. Another major problem of DKI is that these DWI images are usually acquired with an echo planar imaging (EPI) sequence and also require high b-values, resulting in a low SNR of acquired diffusion weighted images. The MRI protocol that we used for DKI acquisitions at 1.5T clinical scanner is chosen with the aim at achieving the above mentioned compromise.
The images were analyzed with a software developed by our research group and able to reconstruct typical DKI maps. This software provides the values of Kurtosis Tensor, Diffusion Tensor, and parametric maps related. Python language was used to develop this software inspired and realized in collaboration with a team of the "Dipy" software project.

#607 - Neuronal signalling viewed through newly designed neurobiosensors

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Neuronal signals timely regulate the function of complex neuronal networks that form the human brain. They are generated by molecular events that derive from rapid conformational changes of integral membrane proteins (ion channels, receptors and transporters). Membrane ion channels and receptors thus generate electrical signals (action potentials), regulate neurotransmitter release (synaptic transmission) and control the activity of complex neuronal networks, allowing for instance, the rapid exchange of information between brain and peripheral nervous system.
Monitoring the signals generated by single neurons or neuronal networks in vitro and in vivo is a central task to understand the molecular basis of the central nervous system physiology and to identify the molecular targets for the treatment of neurodegenerative diseases (Alzheimer, Parkinson, depression, sleep disorders, chronic stress, ...). To date exist a large number of multi-electrode arrays (MEAs) made of different material (TiN, ITO, CMOS, MOSFET, carbon-based, conductive polymers) able to detect the electrical activity of neuronal networks, but exist few examples of *lab-on-chips* capable of detecting the quantal release of neurotransmitters from neurons or neuroendocrine cells with high time resolution and signal-to-noise ratio.
With the idea of developing new planar diamond-based biosensors able of detecting action potentials, synaptic activity and optical signals in neurons and neuroendocrine cells, we have tested a new series of devices made of boron-doped nanocrystalline diamond (NCD-MEAs) (*Gosso et al. J. Physiol., 2014; Conte et al. Phys. Stat. Sol. A, 2015*) and micro-graphitic channels buried on diamond mono-crystals (µG-MEAs) (*Picollo et al. Adv. Mat., 2013; Picollo et al., Sensors, 2015*) of different geometries. The chips, with increasing number of microelectrodes (2x2, 3x3, 4x4, 8x8), are made with sensitive areas of either low- or high-density depending on whether the recordings is from population of cells, excitable tissues, neuronal networks (low-density) or single cells (high-density). In the latter case the chip can resolve the secretory activity of cell micro-domains.
The rational of using these two classes of MEAs to study "neuronal signals" in-vitro and in-vivo will be discussed together with the expected future applications of more advanced devices.

#608 - Heterogeneous mean field approach to neural networks

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We discuss how one can approach the study of neural dynamics in disordered dense uncorrelated networks by a mean--field approach that preserves disorder effects in the thermodynamic limit. The method allows to obtain an effective description of the model at hand by reducing the dynamics of single neurons to the one of classes of neurons characterized by their in-degree connectivity. Moreover, the method allows to solve the global inverse problem of reconstructing the network structure (including the fraction of excitatory and inhibitory neurons) from the properties of the global synaptic activity field.