INTRODUCING TIME-VARYING PARAMETERS IN THE KURAMOTO MODEL FOR BRAIN DYNAMICS

S. Petkoski[1], A. Stefanovska[1]

(1) Department of Physics, Lancaster University, Lancaster LA1 4YB, UK.

Biological examples provided the original motivation lying behind the Kuramoto model (KM) of coupled phase oscillators [1]. However, neither the original model, nor any of its extensions [2], have incorporated a fundamental property of living systems – their inherent time-variability. Many important characteristics of open systems can be missed by not accounting for the non-equilibrium dynamics that stems from their time-dependent parameters.
We introduce a generalization of the KM by explicit consideration of deterministically time-varying parameters [3]. The oscillators' natural frequencies and/or couplings are influenced by identical external force with constant or distributed strengths. The new dynamics of the collective rhythms consists of the external system superimposed on the autonomous one, a characteristic feature of many thermodynamically open systems. This deterministic, stable, continuously time-dependent, collective behaviour is fully described. Additionally the external impact and the reduced dynamics are defined in both the adiabatic and non-adiabatic limits. In this way, a large range of systems tackled by the Kuramoto model - spanning from a single cell up to the level of brain dynamics - can be described more realistically. Namely, experimentally reported [4] results for anaesthetized brain allow it to be modeled using time-varying couplings [5], whereas variability of the neurons' firing rate [6] can be also deterministically encompassed with this model.
The work to be presented helps to describe time-varying neural synchronization as an inherent phenomenon of brain dynamics. It accounts for experimental results reported earlier [4,6] and it extends and complements a previous attempt [5] at explanation.

[1] S. Strogatz Sync: The Emerging Science of Spontaneous Order (Hyperion, New York) (2003).

[2] J. A. Acebrón et al. Rev. Mod. Phys. **77**, 137 (2005).

[3] S. Petkoski and A. Stefanovska, Kuramoto Model with Time-Varying Parameters, preprint, http://arxiv.org/abs/1107.3867

[4] B. Musizza, et al. J. Physiol. **580** 315326 (2007).

[5] J. H. Sheeba et al. Biophys. J. **95**, 2722 (2008).

[6] D. Rudrauf et al. Neuroimage **31**, 209 (2006).