Co-emergence of Multi-scale Cortical Activities of Irregular Firing, Oscillations and Avalanches Achieves Cost-efficient Information Capacity

Dong-Ping Yang[1,2], Hai-Jun Zhou[3], *Changsong Zhou[1,2]

[1] Department of Physics, Hong Kong Baptist University, Kowloon Tong, Hong Kong

[2] Centre for Nonlinear Studies and Beijing-Hong Kong-Singapore Joint Centre for Nonlinear and Complex Systems (Hong Kong), Institute of Computational and Theoretical Studies, Hong Kong Baptist University, Kowloon Tong, Hong Kong

[3] State Key Laboratory of Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Zhong-Guan-Cun East Road 55, Beijing 100190, China

***E-mail: cszhou@hkbu.edu.hk**

The brain is highly energy consuming, therefore is under strong selective pressure to achieve cost-efficiency in both cortical connectivities and activities. However, cost-efficiency as a design principle for cortical activities has been rarely studied. Especially it is not clear how cost-efficiency is related to ubiquitously observed multi-scale properties: irregular firing, oscillations and neuronal avalanches. Here we demonstrate that these prominent properties can be simultaneously observed in a generic, biologically plausible neural circuit model that captures excitation-inhibition balance and realistic dynamics of synaptic conductance. Their co-emergence achieves minimal energy cost as well as maximal energy efficiency on information capacity, when neuronal firing are coordinated and shaped by moderate synchrony to reduce otherwise redundant spikes, and the dynamical clusterings are maintained in the form of neuronal avalanches. Such cost-efficient neural dynamics can be employed as a foundation for further efficient information processing under energy constraint.

Acknowledgments: This work was partially supported by Hong Kong Baptist University (HKBU) Strategic Development Fund, NSFC-RGC Joint Research Scheme HKUST/NSFC/12-13/01, NSFC (Grant Nos. 11275027) and NSFC (Grant Nos. 11225526 and 11121403).