Contribution ID: **20** Contribution code: **K-1** Type: **Keynote**

Astroglia in Neural Circuits: Modeling Synaptic and Network Modulation

Wednesday 18 June 2025 13:50 (45 minutes)

Astroglia, or astrocytes, are a major class of glial cells in the central nervous system. Long considered passive support elements, they are now widely recognized as active and essential components of neural processing. Astroglia engage in complex, bidirectional communication with neurons [1], responding to neuronal input and modulating synaptic activity through diverse molecular and cellular mechanisms. They play crucial roles in regulating extracellular ion concentrations, clearing neurotransmitters, providing metabolic support, and contributing to the formation, maintenance, and remodeling of synapses. These functions establish astroglia as critical regulators of neural circuit dynamics and overall brain function, both under normal physiological conditions and in the context of neurological disorders. To better understand the complex nature of neuron–astroglia interactions in the brain, computational modeling of these processes is essential [2].

In this talk, I will review the main types of neuronal input signals to astroglia and describe the key astroglial mechanisms at both molecular and cellular levels that drive their functional outputs. I will then discuss the consequences of these outputs on brain activity, highlighting their relevance to brain function in health and disease. Furthermore, I will present some of our recent work in developing computational modeling methodologies, including new models and tools aimed at capturing astroglial influence on synaptic [3] and network dynamics [4], with particular emphasis on our astroglia implementations in the NEST simulation platform [5,6]. Finally, I will discuss how astroglial activity may shape brain functions such as synaptic transmission, network excitability, local and global network synchronization, long-distance signal propagation, and, ultimately, learning and memory in the brain.

Acknowledgements

I would like to express my sincere gratitude to the members of the Computational Neuroscience Group at Tampere University, particularly Dr. Tiina Manninen, Dr. Jugoslava Acimovic, and MSc Iiro Ahokainen, for their valuable contributions and continuous support. I am also deeply thankful to the teams of Prof. Markus Diesmann and Prof. Sacha van Albada, including MSc Han-Jia Jiang, as well as to Prof. Hans Ekkehard Plesser, for their insightful input and productive collaboration. The progress toward the NEST implementation would not have been possible without the dedication, expertise, and hard work of colleagues in both Tampere and Jülich.

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Preferred form of presentation

Topic area

Models and applications

Keywords

Speaker time zone

UTC+3

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Primary author: LINNE, Marja-Leena (Tampere University, Finland)

Presenter: LINNE, Marja-Leena (Tampere University, Finland)

Session Classification: Keynote