*Computational analysis and multi-dimensional modeling uncover hyperbolic geometry in whole brain of C. elegans which aids in discovery of neural network states*

Neural responses are influenced by both external stimuli and internal network states. While

network states have been linked to behavioral and stimulus states, little is known about how

sensory inputs are filtered by whole-brain activity to downstream motor neurons. Using calcium imaging in a Zeiss Airyscan 880, we recorded whole-brain activity of *Caenorhabditis elegans* (*C. elegans)* experiencing bacterial food stimuli and modeled how sensory inputs affect sensory and motor neurons in a network state dependent manner. We classified active neurons into six functional clusters: two sensory neuron clusters (ON, OFF), and four motor/command neuron clusters (AVA, RME, SMDD, SMDV). We proceeded to analyze our multi-dimensional calcium trace data without losing the distance measures between points using a hyperbolic embedding technique, Hyperbolic Multidimensional Scaling (HMDS). We determined that there was a hierarchical structure among the neuronal populations. Bayesian information criteria analysis showed that our data can be optimally represented in 8-dimensional space. These dimensions correspond to the axes of 4 different sets of complementary neurons corresponding to the cell types we identified. Although neural computations performed by sensory neurons are linear due to their direct exposure to stimuli, the downstream neurons are often non-linear as they integrate inputs from multiple neurons. This non-linearity poses a challenge in interpreting downstream neural responses that correspond to their original input stimuli. Our goal is to analyze how input stimuli and sensory neurons affect downstream motor neural populations. We used low rank second order maximum noise entropy, which recapitulates the nonlinear filter dynamics within neural populations allowing us to identify specific states of the network that links sensory neuron activity with downstream motor neurons. Collectively, we present an interpretable approach for modeling network dynamics of neural populations.

Keywords: *C. elegans, whole-brain imaging, network states, sensory gating*