Summary: Staying upright is a fundamental prerequisite for survival: animals must continuously transform vestibular signals about gravity and motion into corrective motor commands. When this transformation fails, balance becomes unstable—a hallmark of many neurological and vestibular disorders. Yet we still do not understand how vestibular signals are transformed into distinct corrective motor programs, nor how circuit dynamics set the timing limits that determine the speed and stability of postural control.

This project aims to build an end-to-end explanation of vestibulo-driven postural control in a transparent vertebrate model, the larval zebrafish. We will combine (i) a unique free-swimming “inverted gravity” paradigm, in which magnetic forces applied to otoliths in the inner ear perturb the animal’s perceived gravity and thus robustly elicit full-body rotational righting into a stable ventral-up posture; (ii) high-speed, multi-view video recordings of this behavior with AI-based tracking to quantify the complete behavioral repertoire and its precise temporal sequence; and (iii) brain and spinal voltage imaging during controlled fictive vestibular stimulation to resolve fast neural activation sequences, identify spinal recruitment rules, and identify the neural integration center underlying a ~200 ms sensorimotor delay that we observed in our preliminary data. The proposal leverages complementary expertise at LJP (behavioral analysis, magnetic vestibular actuation, and whole-brain functional calcium mapping) and IPNP (high-speed 3D voltage imaging and extensive expertise in spinal microcircuits).