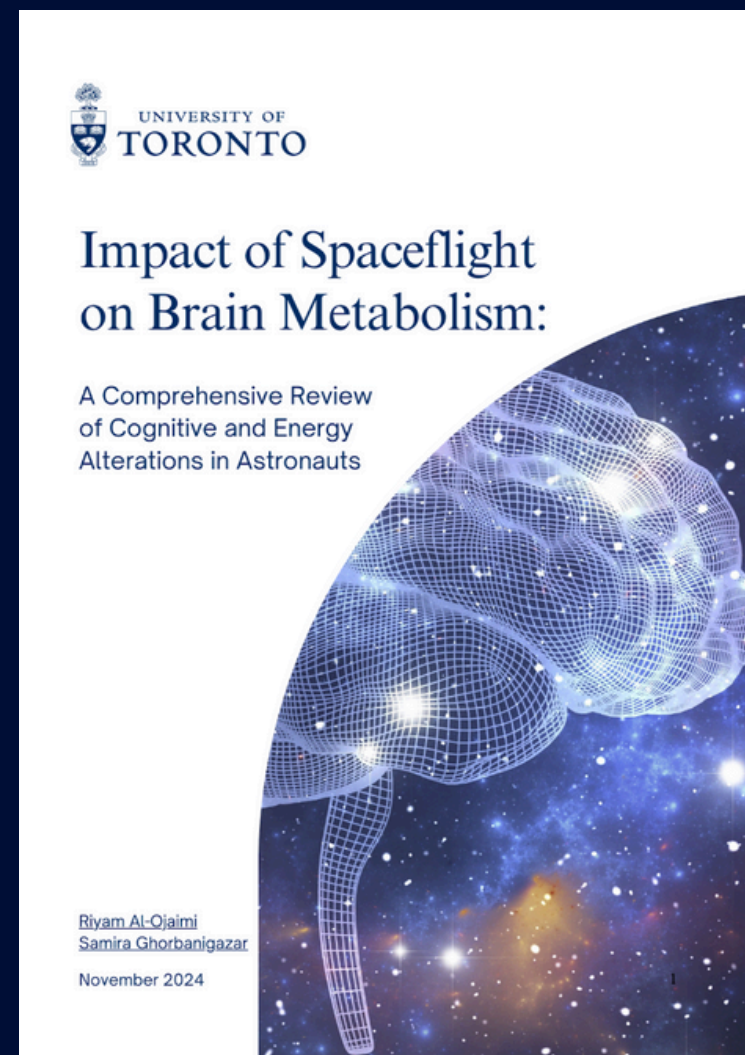
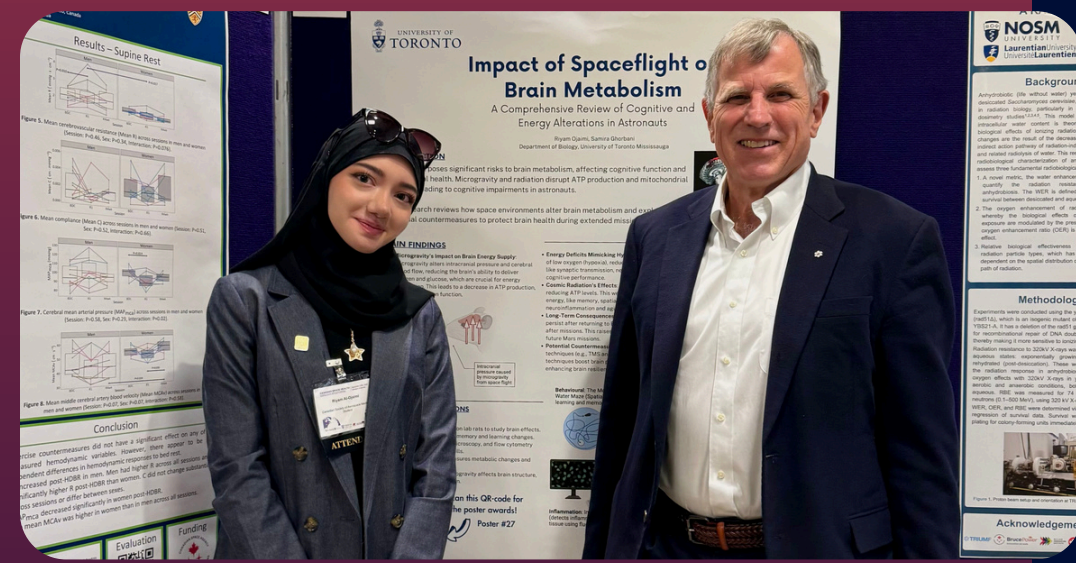
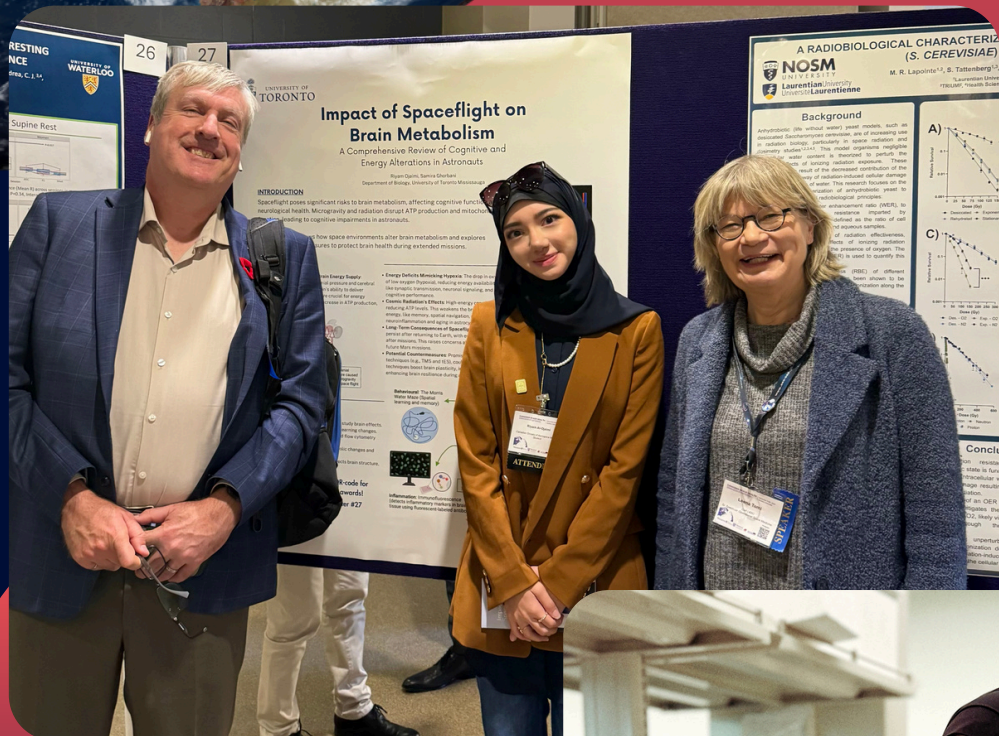


# Impact of Spaceflight on Brain Metabolism: A Comprehensive Review of Cognitive and Energy Alterations in Astronauts





# About me







# Why This Research Matters

- The brain comprises ~2% of body mass yet consumes 20–25% of total oxygen.
- Astronaut cognition = mission-critical.
- Energy disruption → cognitive decline, impaired judgment, neuroinflammation.

Small disruptions can lead to issues with focus, coordination, and decision-making, which are critical for mission safety.





# Background: How the Brain Uses Energy on Earth

## Key Mechanisms:

- Glycolysis → TCA Cycle → Oxidative Phosphorylation
- Astrocyte–Neuron Lactate Shuttle (ANLS) regulates energy transfer
- Neurovascular coupling maintains metabolic–hemodynamic balance





# Physiological Disruption in Spaceflight

## Major Stressors:

- Microgravity → cephalad fluid shift → ↑ intracranial pressure (ICP)
- Galactic Cosmic Radiation (GCR) → mitochondrial DNA damage
- Circadian & psychosocial stress → neurotransmitter imbalance



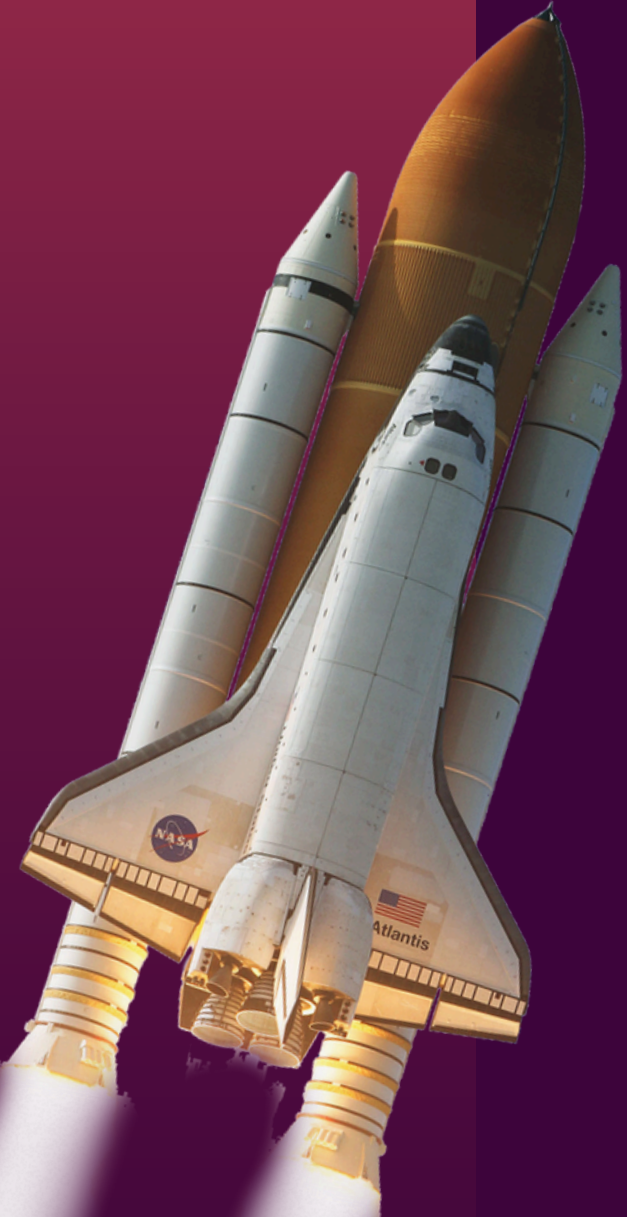


# Mitochondrial Dysfunction and ATP Deficit

- Impaired oxidative phosphorylation → ↓ ATP synthesis
- ↑ Reactive Oxygen Species (ROS) → oxidative damage
- Altered astrocyte reactivity & glucose uptake
- Chronic neuroinflammation and cellular senescence

## Radiation Exposure and Cellular Effects

- Ionizing Radiation (50–2,000 mSv/mission):
- DNA double-strand breaks (DSBs)
- Microglial activation → cytokine release
- Impaired glucose metabolism and lactate transport
- Potential neurodegenerative risk (Alzheimer-like patterns)







# Functional MRI Evidence: 169 days on the ISS Study

169-day ISS Mission:

- ↓ Connectivity: right insula, cerebellum, motor cortex
- ↑ Task activation: compensatory adaptation
- Vestibular network disruption → proprioceptive drift

## Cognitive and Behavioral Correlates

- Impaired spatial orientation and executive function
- Slowed reaction times and altered sensorimotor control
- Disrupted memory consolidation and sleep-dependent learning



# Strengths and Gaps in Current Literature

## Strengths:

- Multi-modal neuroimaging (fMRI, PET)
- Integration of metabolic and neurochemical biomarkers

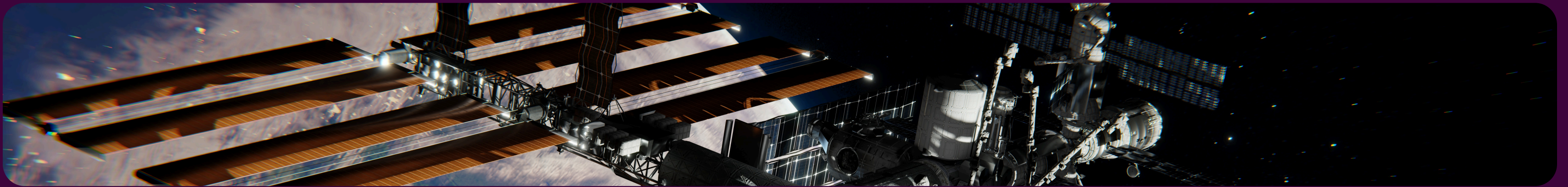
## Gaps:

- N = small (<20 astronauts)
- Post-flight bias; minimal in-flight neuroenergetics data
- Limited molecular insight into astrocytic–neuronal dynamics





# Emerging Countermeasures



## Potential Interventions:

- Exercise & nutritional protocols → optimize mitochondrial biogenesis
- Pharmacological antioxidants (NRF2 activators, CoQ10)
- Noninvasive Brain Stimulation (NiBS):
  - tDCS/tES → enhances cortical excitability, working memory
  - TMS → boosts executive function, cognitive resilience

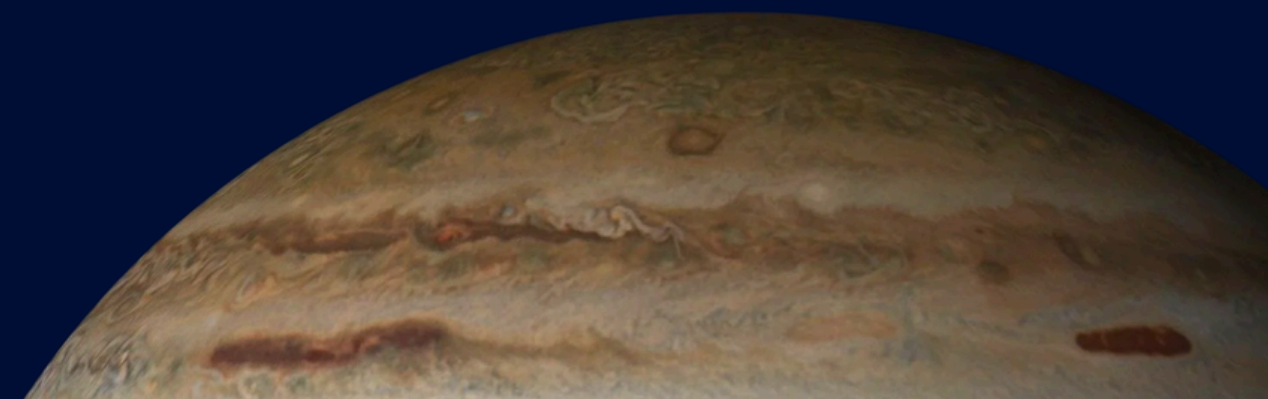




# Future Research Pathways

## Next Steps:

- Simulated microgravity and hypoxia models (rodent + cell cultures)
- Metabolomic profiling of ATP, lactate, and ROS pathways
- Integration with omics-based biomarker detection (proteomic, transcriptomic)
- Collaborations for in-flight monitoring technologies







**Thank you!**