M2 INTERNSHIP PROPOSAL

Specialty: Theoretical Physics

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Analysis of communities in vascular networks and their influence on blood flow in the brain and on degenerative diseases.

This M2 internship aims to study the cerebral vascular network using the tools of network physics. In particular, it will seek to analyze the communities present in cerebrovascular networks and understand their role in reducing blood flow in the brain. This reduction plays a significant role in triggering cerebrovascular diseases, such as hypoperfusion dementia or Alzheimer's disease. The supervising team includes a specialist in blood flow mechanics [1,2] and physicists with expertise in network theory [3,4]. A study has already been conducted [5] by the supervisors, demonstrating the importance of the presence of communities in the reduction of blood flow in a specific case. The internship will aim to analyze the significance of this community structure, its biological origin, and its role in reducing blood flow in more general cases. The internship will utilize mathematical tools from network theory and experimental data from real vascular networks.

This internship is part of an interdisciplinary project aiming to develop a new approach to studying blood circulation in the brain and its effect on degenerative diseases. The internship will be supervised by a team of researchers from the Laboratory of Theoretical Physics and the Institute of Fluid Mechanics in Toulouse, which has connections with biology and medical laboratories studying the brain in France and abroad. The internship will also be conducted in collaboration with Olivier Giraud from the Laboratory of Theoretical Physics and Statistical Models at Paris-Saclay University. The project will require both numerical simulations and analytical calculations. Depending on the candidate's academic level and motivation, the internship could lead to a PhD (funding for a PhD is currently being applied for but is not yet guaranteed).

[1] F. Goirand, T. Le Borgne and S. Lorthois, “Network-driven anomalous transport is a fundamental component of brain microvascular dysfunction”, *Nature Communications* **12**, 7295 (2021).

[2] A. Ahern, T. B. Thompson, H. Oliveri, S. Lorthois and A. Goriely, “Modelling cerebrovascular pathology and the spread of amyloid beta in Alzheimers disease”, Proceedings of the Royal Society A **481**, 20240548 (2025).

[3] C. Coquidé, B. Georgeot and O. Giraud, ”Distinguishing humans from computers in the game of go : a complex network approach”, EuroPhysics Letters **119**, 48001 (2017).

[4] T. Frottier, B. Georgeot and O. Giraud, ”Harmonic structures of Beethoven quartets : a complex network approach ”, Eur. Phys. J. B **95**, 103 (2022).

[5] F. Goirand, B. Georgeot, O. Giraud and S. Lorthois, “Network Community Structure and Resilience to Localized Damage: Application to Brain Microcirculation” Brain Multiphysics **2**, 100028 (2021).