INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: NO, Application to ED PIF PhD grants possible

Intermittent behaviour and the emergence of collective phenomena in biological systems

Collective behaviours are ubiquitous in nature — from flocks of birds flying across the sky to groups of bacteria moving in response to chemical concentrations. When individuals interact within a group, they often display behaviours and properties that are absent in isolated individuals. These **emergent phenomena** give rise to complex patterns and dynamics that cannot be directly predicted from single-agent behaviour.

Among the various collective phenomena observed in biological systems, this internship will focus on **intermittent collective motion (ICM)**. This phenomenon occurs when coordinated movement alternates between **active phases**, where individuals move together cohesively, and **inactive or disordered phases**, where movement slows, stops, or becomes uncoordinated. In other words, collective motion does not occur continuously but **in bursts of synchronization** separated by pauses or scattered activity. This type of dynamics has been observed in **gregarious animals such as sheep** [1,2] and **fish** [3].

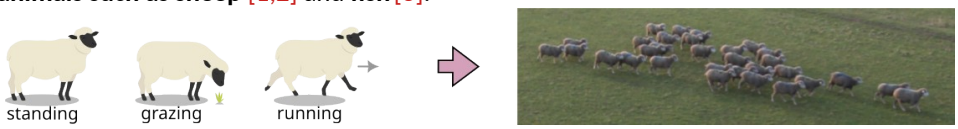

Figure 1: Left: Scheme of intermittent motion behaviours that individual sheep can adopt over time. **Right:** Snapshots of the emergent **Intermittent Collective Motion** observed in groups of 32 sheep [4].

The project will aim to **model the consensus process** that occurs at the beginning and end of each **collective motion phase**, using a computational framework to capture the mechanisms driving these transitions. Model validation will be achieved by **comparing numerical simulations with available experimental data** from groups of sheep [1,2]. To quantify ICM dynamics, **we will measure observables at both the individual and collective levels:** at the individual level, each individual's position relative to the group centre and its average times of motion and rest; at the collective level, group displacement (mean squared displacement), cohesion (inter-individual distance), and alignment (polarization). This multi-scale comparison will ensure that the model faithfully reproduces experimental dynamics.

Finally, we will use numerical simulations to explore the **robustness** of the inferred mechanisms under controlled conditions that are difficult to reproduce experimentally, such as the **presence of obstacles** or **potential leaders that trigger the collective motion.** We will also investigate **how coordination scales with group size**, testing whether the same interaction rules hold across different group configurations or whether **individuals adapt their behaviour accordingly.**

Required skills: the candidate should have a strong inclination for theory (especially statistical physics & active matter), numerical simulations, as well as (some) experience on analysing experimental data.

References

[1] L. Gómez-Nava et al., "Intermittent collective motion in sheep results from alternating the role of leader and follower", ***Nature Physics*** (2022). [**link**]
[2] F. Ginelli et al., "Intermittent collective dynamics emerge from conflicting imperatives in sheep herds", ***PNAS*** (2015). [**link**]
[3] L. Gómez-Nava et al., "Fish shoals resemble a stochastic excitable system driven by environmental perturbations", ***Nature Physics*** (2023). [**link**]
[4] S. Toulet et al., "Imitation Combined with a Characteristic Stimulus Duration Results in Robust Coll. Decision-Making", PLOS One (2015). [**link**]

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:
Condensed Matter Physics: *NO* ***Soft Matter and Biological Physics:*** *YES*
Quantum Physics: *NO* ***Theoretical Physics:*** *YES*