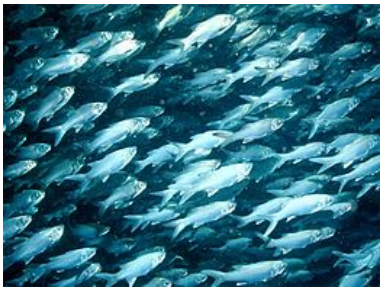
M2 internship and/or PhD thesis

Are leaders useful, and when ?

Numerous experimental and modeling studies provide new insights into the mechanisms of effective leadership and decision-making in actual biological systems, from sheeps to fish schools or starlings. They have begun to establish the link between individual behaviour and collective movement, and to study in detail how a few informed individuals can influence the decision of a large group, for instance to find a shelter or a food source.



Sheeps and fishes sometimes move collectively with identified leaders, and sometimes not. Under what conditions, and for which tasks, is one option more efficient than the other ?

This internship, jointly supervised by physicists José Halloy and François Graner, will address a different question, independent of any specific system : *Under which conditions is the presence of one or a few leaders an advantage in term of efficiency, and when is it a drawback ?* The study will built on numerical simulations of well-defined tasks, for which the efficiency of the collective group response can be quantitatively assayed.

A first step, suitable for an internship, consists in studying a simple task, that of decision to find food. The model used will be based on velocity correlations between neighbours (the classical Vicsek model). The collective efficiency will be measured with respect to one dimensionless parameter, the correlation length to group size ratio, which quantifies the quality of information propagation within the group. It will be simulated both without and with one leader, yielding two increasing curves which intersect. This will enable to determine the type of transition from leader-led to leaderless groups. The same will be repeated for another task, that of quick response to a predator arrival.

More detailed studies, suitable for a PhD thesis, involve both statistical physics and non-linear physics. It will test numerous model ingredients, and the robustness of the results with respect to such changes. Other tasks will include spatial structuration of the group, collective migration, collective building. The efficiency will be measured, at the level both of the individual and of the group, in terms of energy consumption, precision of the asymptotically reached state (either a stationnary state or an attractor), convergence type and characteristic time of the transient regime required to reach the final state. A global phase diagram will be progressively established, and compared with analytical studies where the group is considered as a continuous medium.

Different definitions of a leader will be implemented and compared : either informed individual, decision-maker, or quicker-moving individual. The advantages and drawbacks of leader presence will be analyzed in terms of group cohesion, robustness of the decision procedure, and integration of possibly conflicting informations. The number of leader will be varied, and it will even be determined under which conditions leaders could emerge from a preciously undifferenciated group.

This entirely original reasearch combines advanced modelling tools with deeply fundamental questions. It should turn attractive for a creative student, either physicist or engineer, with a taste for programming and cross-disciplines discussions.

Contact : Jose.Halloy@univ-paris-diderot.fr
Francois.Graner@univ-paris-diderot.fr
Paris Interdisciplinary Energy Research Institute
Complex Systems and Matter