Fish swarming

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Schools of fish are known to produce marvelous dynamics, that allows them to fool predators and to find food efficiently. To model these phenomena, two main models exist: the *Couzin-Vicsek model*, and the *Cucker-Smale model*. In both models, the individuals are interacting: for the first model, individuals tend to align with their neighbors, while for the second model, individuals tend to aggregate (if they are isolated, they swim towards their peers, while if they feel overcrowded, they try to swim away from their neighbors). Numerical simulations of either of those models lead to pattern formation that are similar to the ones observed in nature.

For the *Couzin-Vicsek model*, Pierre Degond, Amic Frouvelle and Sebastien Motsch have introduced a new idea to derive macroscopic models. Those macroscopic limit, or *hydrodynamic limits*, play a central role in fluid dynamics: they are the connections between kinetic models (Boltzmann equations) and Euler/Navier-Stockes equations. Using similar limits for biological models is a appealing idea, and it could provide biologists explicit connections between several existing models. These limits in physical models are however based on conserved quantities (momentum, energy), that do not exist in most biological settings. New ideas are then necessary, and the *Generalized Collision Invariant* introduced by Pierre Degond, Amic Frouvelle and Sebastien Motsch is a first step in this direction.

The idea of *Generalized Collision Invariant* is to relax the notion of conserved quantities to "quantities conserved with respect to a certain class of test functions". The authors indeed show that collisions invariants (that are directly related to conserved quantities) is an un-necessarily strong idea to derive macroscopic models, and that a weaker for of those invariants is enough. This generalized form can be used in the case of the Couzin-Vicsek model.

The project will be based on the following articles:
P. Degond, S. Motsch, Continuum limit of self-driven particles with orientation interaction, *M3AS* **18**(1) (2008).
Pierre Degond, Amic Frouvelle, Jian-Guo Liu, Sebastien Motsch, Laurent Navoret, Macroscopic models of collective motion and self-organization, *Séminaire Laurent Schwartz — EDP et applications*, (2012-2013).