Self-organisation in nature: patterns and bifurcations in nonlocal advection-diffusion models

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Understanding the mechanisms underlying the self-organisation of mobile organisms is a central question in ecology and biology. In nature, individuals - whether cells or animals - sense their environment before moving. This process is typically nonlocal, as information is gathered from a wider region rather than just the immediate surroundings. Empirical studies highlight nonlocality as a key feature of movement, and mathematical models that incorporate it are increasingly used to describe self-organisation in biological systems. Beyond capturing some real-world phenomena more faithfully, nonlocal models also exhibit rich dynamics, making them of interest to both modellers and analysts.

In this talk, I will present a class of advection–diffusion equations modelling population movement driven by nonlocal species interactions. Using analytical and numerical techniques, I will show that these models support a wide range of spatio-temporal patterns, including segregation, aggregation, time-periodic dynamics, and chase-and-run phenomena. I will also discuss parameter regimes exhibiting multiple stable solutions and hysteresis effects.

Overall, I will highlight methods for analysing bifurcations and pattern formation in these models, which provide essential mathematical tools for understanding self-organisation and emergent phenomena in nature.