Suggested title of dissertation:

Reaction-diffusion on higher-order networks

Dissertation supervisor:

Dr Renaud Lambiotte

Description of the proposal:

An important feature of complex systems is that system components may influence each other either directly or indirectly. Within a network language, direct interactions are encoded by edges and indirect interactions by paths. Impact on dynamics is then explored by endowing either nodes or diffusing entities with dynamical states. Network architectures tend to exhibit short paths between different parts of the system, together with a small number of connections. Important underlying assumptions are that paths are built from a memoryless, transitive closure of direct interactions, and that interaction events can be described by Poisson processes. Departure from either of these conditions leads to non-Markovian dynamics. The main purpose of these projects will be to explore how non-Markovianity in path or in time will affect reaction-diffusion processes on networks.

Possible avenues of investigation:

- Collection and analysis of non-Markovian paths from empirical network data
- Design of meta-population models for epidemic spreading and synchronisation with non-Makovian dynamics
- Study of the conditions for epidemics or synchronisation to emerge on systems with non-Markovian pathways, described by higher-order Markov models
- Study of the conditions for epidemics or synchronisation to emerge on systems with non-Poisson inter-event times, described by generalised master equations.

Pre-requisite knowledge:
Essential: A0: Linear Algebra (`https://courses.maths.ox.ac.uk/node/37618`)

Recommended: C5.4 Networks (`https://courses.maths.ox.ac.uk/node/36869`) and B5.6 Nonlinear Systems (`https://courses.maths.ox.ac.uk/node/36426`)

Useful reading:

- Temporal Networks, P Holme, J Saramki, Physics Reports 519 (3), 97-125 (2011)
- Networks: an introduction, M Newman, Oxford university press (2010)
- Turing patterns in network-organized activatorinhibitor systems, H Nakao and AS Mikhailov, Nature Physics 6, 544550 (2010)

Further references:

- Memory in network flows and its effects on spreading dynamics and community detection, M Rosvall et al., Nature Communications 5, 4630 2014
- Mean-field models for non-Markovian epidemics on networks, N Sherborne et al., Journal of mathematical biology 76 (3), 755-778 2018
- Critical regimes driven by recurrent mobility patterns of reactiondiffusion processes in networks, J. Gmez-Gardees et al., Nature Physics, 391395 (2018)
- Voter model with non-Poissonian interevent intervals, T Takaguchi and N Masuda, Phys Rev E 84, 036115 (2011)
- Diffusion on networked systems is a question of time or structure, JC Delvenne et al., Nature Communications 6 (2015): 7366.