Long-range Contact Process in a Random Environment

PhD Candidate: Frank Namugera

BSc. (MAK), MSc. Math (AIMs), MSTA. (MAK),

Supervisors:

- Prof. Stein Andreas Bethuelsen (Math Dept., University of Bergen, Norway)
- Dr. Onesfole Kurama (Math Dept., Makerere University, Uganda)
- Dr. Symon Peter Wandiembe (SSP, Makerere University, Uganda)
- Prof. John M. Mango (Math Dept., Makerere University, Uganda)

Abstract

We consider a general class of contact processes on a d-dimensional integer lattice ($\mathbb{Z}^d$), allowing for long-range interactions. By adapting classical renormalization arguments, we extend well-known results for the case where the infection parameter has a finite range to this more general setting under certain assumptions on the decay rate. Particularly, we show that a supercritical process remains supercritical after truncation of the interaction parameter at a sufficiently large distance. Further, for families of parameters satisfying this latter truncation property, we conclude that the probability of the process never to recover is continuous.

To further assess the impact of long-range dynamics on complex networks, we extend this concept into environments that incorporate aging, cooperation, and competing strain models. Using discrete-time nonlinear dynamical systems, we show that contagion dynamics are highly sensitive to both environmental randomness and long-range couplings in both cooperative and competitive models. Furthermore, statistical analyses reveal that the epidemic survival significantly depends on the spatial decay exponent (α) and the scale-free graph exponent (γ). Particularly, these exert pronounced, nonlinear, and time-dependent effects on the survival of competing strains.

Finally, by means of a mean-field analysis, we demonstrate that the survival function in a contact process with aging model depends on three exponents: the spatial decay exponent (α), the recovery exponent (δ), and the infectivity exponent (γ). We show that (α) predominantly controls the threshold behavior. However, as spatial interactions become increasingly localized, the temporal exponents (δ , γ) play a dominant role. In particular, slower recovery ($\delta < 1$) enhances memory effects and spatial correlations, promoting infection persistence and lowering the critical contagion rate (λ_c), whereas faster recovery suppresses local clustering and raises the threshold. These results reveal how non-Markovian temporal dynamics and long-range spatial coupling interact to shape critical behavior in epidemic processes on complex networks.