Where higher order of interactions matters?

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Susceptible-Infective-Susceptible (SIS) and Susceptible-Infective-Recovered (SIR) are two successful models for understanding spreading dynamics -non-linear dynamics- like disease spreading. However, the complexity of the problem is even higher, as diseases can interact between themselves in several ways, inducing higher susceptibility or cross-immunity. These interactions increase in any public contact networks. For example, several cases of coinfection in hospitals have been reported. As another example, Murray et.al. estimated a potential pandemic could kill between 50 and 80 million people by having a virulence strain similar to the 1918 influenza today. In these cases, the number of affected agents vs infection rate may dramatically change, i.e. first order phase transitions. Here we want to understand how microscopic mechanisms might lead to unexpected macroscopic outbreaks; Thus in this work, we study spreading of two dynamics: either cooperative or competitive interacting as a SIS or/and a SIR dynamics and address similarities and differences in comparison to other minimal cooperative models, i.e. SIR-SIR [1] and SIS-SIS [2]. We propose a model and treat it in mean field approximations as well as stochastic agent based models. We show an emerging region in the parameter space where the stable endemic and stable free-disease states co-exist. This region appears differently in presence of cooperation or competition. Also we show how this region might be affected by topological features of the contact networks, e.g. generated random networks as well as empirical networks. These mathematical modelling of disease spreading can help on one hand to widen our views on critical phenomena, specifically hybrid transitions. On the other hand, these can help us to improve our understanding how diseases spread in networks and guide policy makers for better strategies to avoid large outbreaks.

[l] W. Cai, et. al., Nature Phys. **11**, 936 (2015).

[2] P. Grassberger, et. al., EPL **104**, 50001 (2013).

[3] L. Chen, et. al., Phys. Rev. E **93**, 042316 (2016).